ASTRONOMY

May 1982
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Observing Edge-On Galaxies

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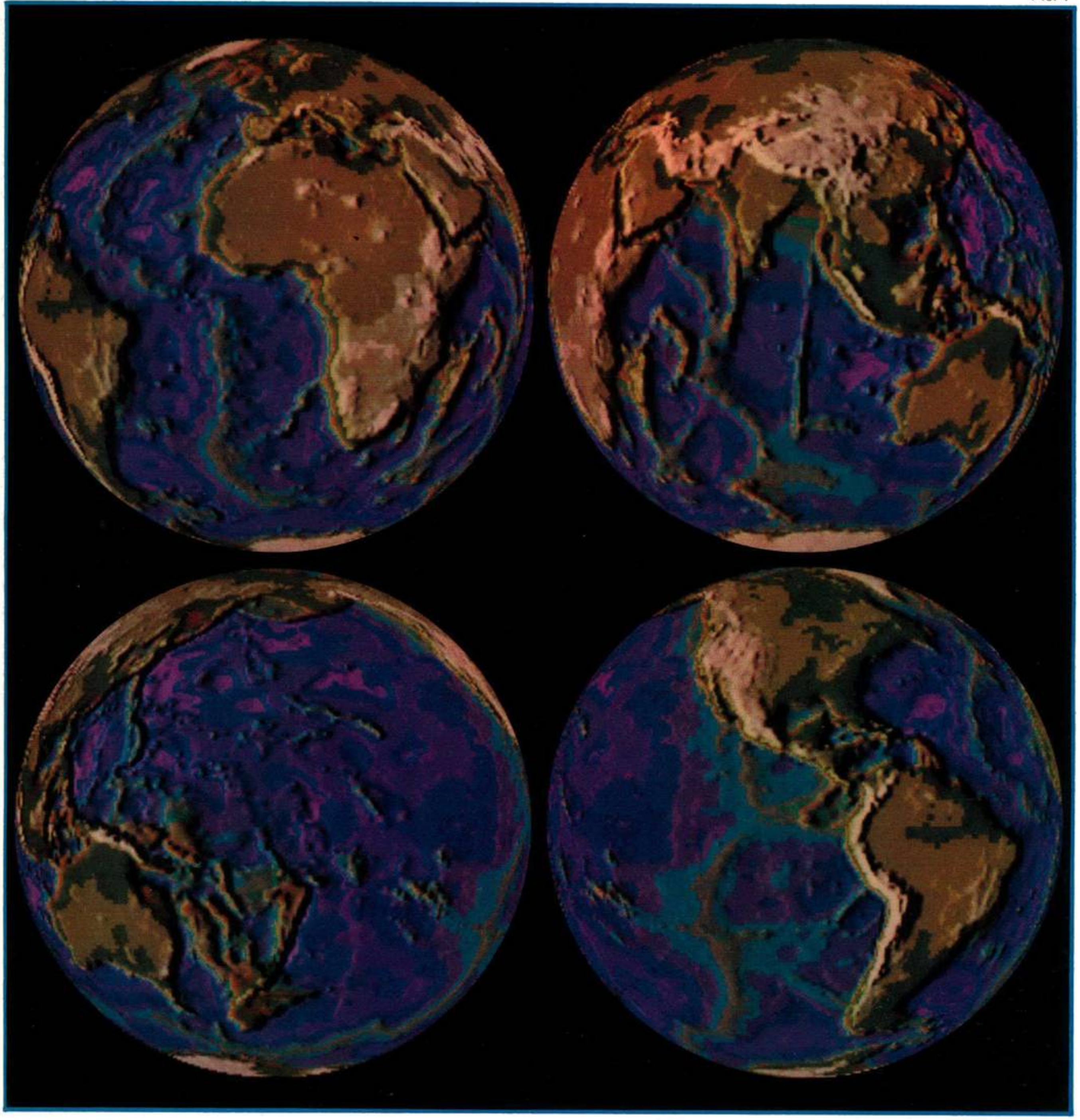

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Dr. John C. Diebel, President
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Dear Dr. Diebel:

We have enjoyed some excellent 'seeing' recently, so last night I was delighted with the chance to do some serious observing through my Meade 2080.

I tried the double star Castor first—a fairly nasty test for glare and scatter, as the components are both bright and close. While the 2080 resolved this double with ease, the thing I particularly noticed was the Airy disc—smaller, harder, and sharper than in other Schmidt-Cassegrains I've observed with, and I've observed with them all at one time or another. Even at 450X, the stellar diffraction rings were very well formed and symmetrical.

Then I tried the first-quarter Moon. Here the 2080 won hands down for image contrast over other Schmidt-Cass's I've used. Your baffling really works! At powers from 200X to 450X, the image was extremely sharp and the resolution excellent.

Finally, I aimed the 2080 at Jupiter and noted (a) very good contrast between the planet and the sky background, and (b) the same high contrast ratio between the cloud belts and the brighter portions of the planet's disc. There is little doubt in my mind but that the 2080 is a very high-performance instrument. In sum, I am impressed.

Yours very truly, Leo Henzl

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***Telescopes Shown:** (top) Meade 8" Model 2080 with optional photographic systems; and (bottom) Meade 10" Model 2120 with optional 2" f/12 Photo-Guide Telescope.*

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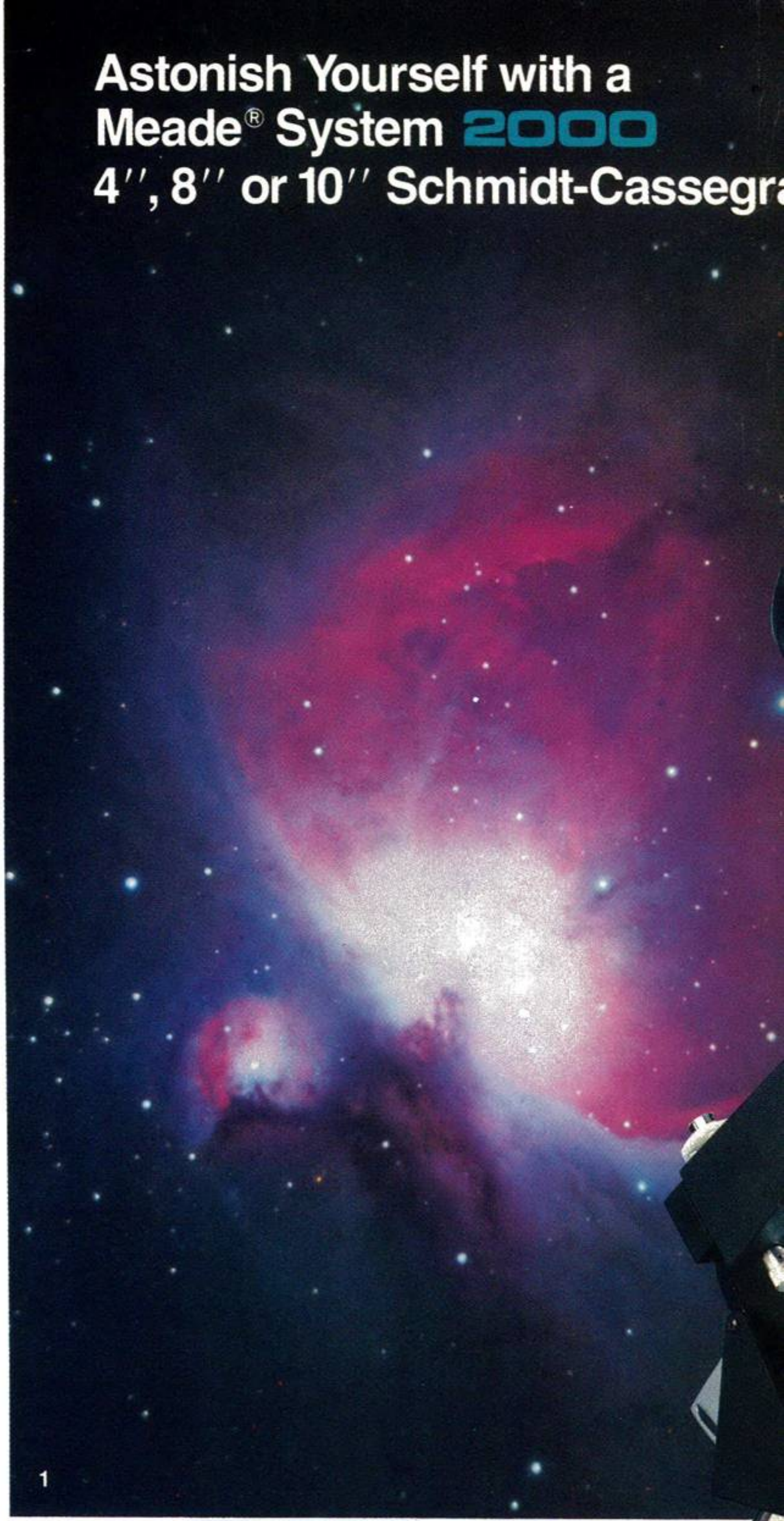

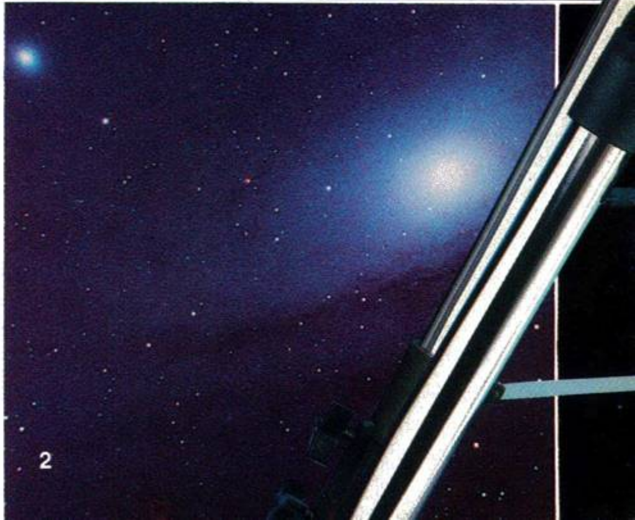

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All astrophotographs shown on these pages were taken through off-the-shelf, unmodified Meade 8″ Model 2080 Schmidt-Cassegrain telescopes. For further technical details on these and many other astronomical photographs, send for your free copy of the Meade Schmidt-Cassegrain Astrophoto Brochure. (Alternately, the complete Meade 52-page General Catalog is available at $3.00 by First Class Mail and includes the Astrophoto Brochure at no additional charge.)

Key to Photographs
1, 2, 3, 5, 7 — Leo Henzl; 4, 6, 8 — Emery Hildebrand;
9 — John Sanford

1. Orion Nebula M42; exposure time 50 mins. **2.** Andromeda Galaxy M31; 60 mins. **3.** Galaxy M82; 60 mins. **4.** Milky Way in Sagittarius (50mm piggyback photo). **5.** Spiral Galaxy M33; 75 mins. **6.** Spiral Galaxy M51; 60 mins. **7.** Galaxy NGC 253; 40 mins. **8.** Omega Nebula M17; 40 mins.; **9.** Moon — Clavius region; 1-sec.

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Cover: How do the rocky landforms of planet Earth resemble the topographies of the other planets? The first step in answering this question is to strip away the oceans, then "blur" our view of Earth until it's as detail-reduced as our views of Earth's "sister planet" Venus and smaller Mars. These pages: Three terrestrial planets, all to the same scale, show differing topographies. Earth has low ocean basins and continental plateaus, Venus has a vast global plain with a few plateaus, and Mars has a gigantic volcanic construct on one side. Orthographic projections generated at JPL.

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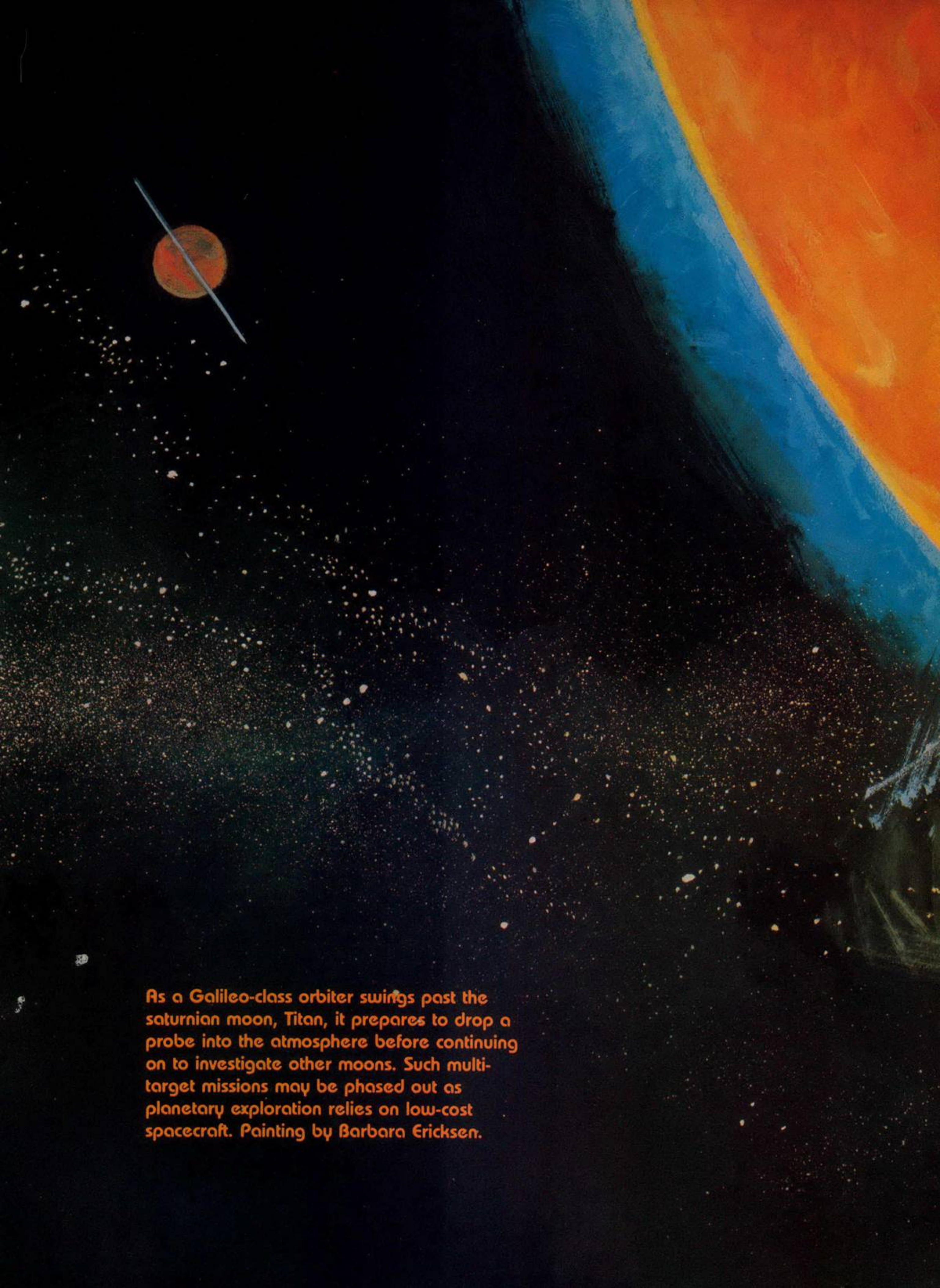
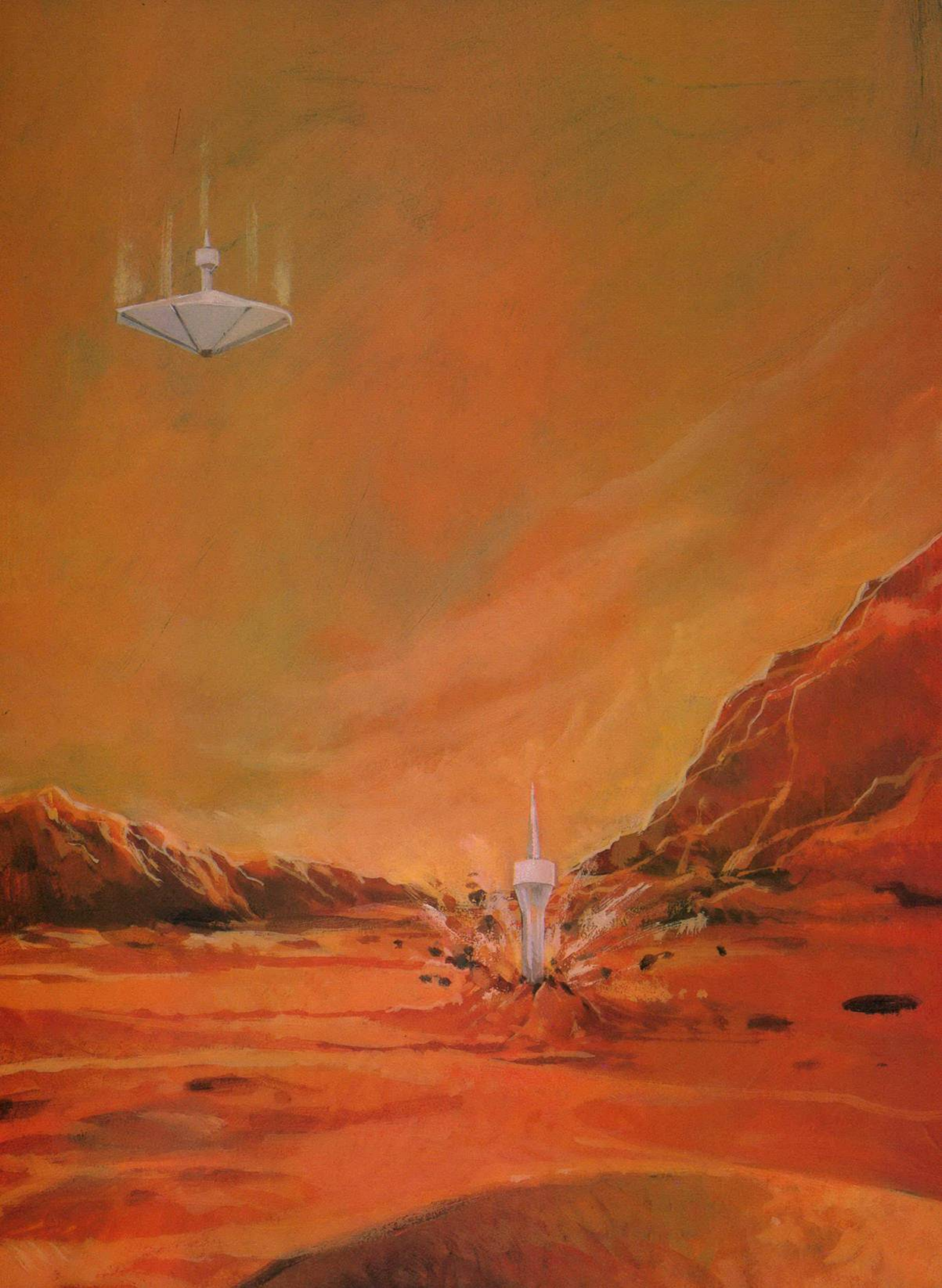


As a Galileo-class orbiter swings past the saturnian moon, Titan, it prepares to drop a probe into the atmosphere before continuing on to investigate other moons. Such multi-target missions may be phased out as planetary exploration relies on low-cost spacecraft. Painting by Barbara Ericksen.

the Planets or Bust

by Van Kane



After the spectacular results of Viking, Pioneer Venus, and Voyager, it's easy to forget how close America's planetary exploration program has come to extinction. During the 1960s the U.S. launched 32 unmanned planetary and lunar craft; the next decade followed with only 11. For the 1980s NASA has approved a single mission — the twice-delayed Galileo Jupiter orbiter and atmospheric probe. However, budget cuts continue to threaten even this approved program. By one estimate, 40% of the planetary scientists who have worked on these missions will move on to healthier disciplines in the next few years, because of the uncertain economic climate that threatens NASA.

NASA began the decade with a catalog of missions. It intended Galileo as part of an armada that included a lunar orbiter, a Uranus flyby with atmospheric probe, a Mars rover or sample return, a comet rendezvous, a Saturn orbiter with atmospheric probes, and Venus Orbiting Imaging Radar (VOIR). All would have advanced planetary studies; several might have revolutionized them. However, since 1975, the White House — and sometimes Congress — has rejected each year's proposed mission.

"The situation is worse than most people think," says Harold Masursky of the U.S. Geological Survey and a member of NASA's Solar System Exploration Committee, a group of scientists and mission planning experts drawing up a new program for exploring the solar system. "The continuing funding decrease can't even keep the present stretched-out program going."

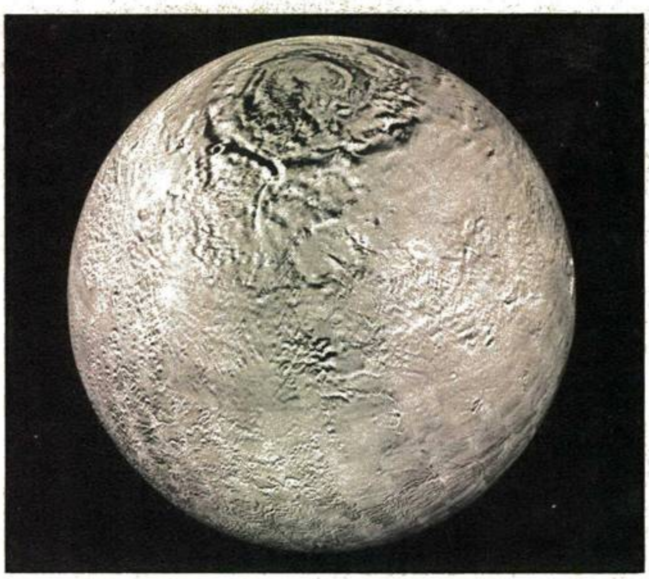
With the new administration slashing federal spending, more money for NASA seems unlikely. As part of its strategy for preserving exploration with comparatively little funding, the committee wants to resurrect a class of low cost missions to help revive the planetary program.

The last two Pioneer series spacecraft reached Venus in December of 1978. Before them an onslaught of previous American and Soviet flybys, orbiters, and landers had left scientists with many puzzles, but little solid information about that world's atmosphere and weather. In what was actually two missions in one, the Pioneers and their four atmospheric probes gave the researchers the information they needed. As a bonus, the orbiter made the first global maps of Venus' surface. Scientists restricted the total cost of that project to less than half that of Galileo or VOIR simply by following these four basic ground rules:

— *Focus the science.* The Galileo orbiter will be a meteorology-geology-magnetospheric-science-platform-all-in-one. Pioneer Venus concentrated primarily on the atmosphere.

— *Hold down the data rate.* Galileo will transmit a picture to Earth in less than a minute. The Pioneer Venus orbiter took more than two hours to transmit the same amount of data.

Using a method developed to deploy nuclear warheads, NASA plans to pepper the surface of Mars with as many as six penetrator-type probes dropped from an orbiter. After impact they will monitor seismological activity and the presence of water vapor on the surface — and transmit the information back to the orbiter. Painting by Barbara Ericksen.



The general-purpose Mariners and Vikings took a global view of Mars during the 1970s. The next generation of spacecraft will be designed to answer specific questions. Mariner 9 image mosaic.

— *Keep mission operations simple.* Galileo will need a large engineering staff to guide it through the mission. Pioneer Venus used just a few support personnel because it followed a simple, repetitive routine.

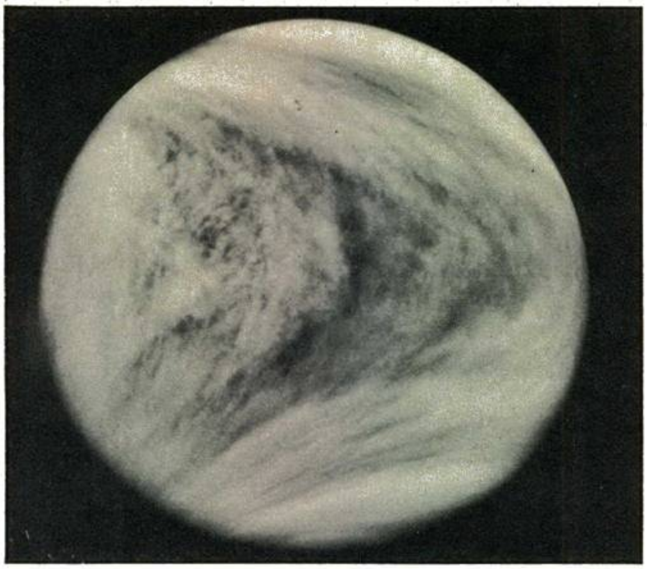
— *Simplify the design.* Galileo will use a unique design incorporating challenging new technologies. Pioneer Venus used proven designs tested on other spacecraft wherever possible.

Over the past decade, various people proposed Pioneer class missions for every planet except Pluto. Only Pioneer Venus and the earlier Pioneer Jupiter-Saturn projects got off the ground. The reasons varied.

When NASA began planning a follow-up Jupiter mission, it had a choice between a Pioneer orbiter or the twice-as-expensive Galileo orbiter. The two craft had equal ability to deploy atmospheric probes and to explore the key regions of the magnetosphere. But Pioneer, with its limited power, communications, and instrument pointing, couldn't study the jovian weather or map the terrain and composition of the major moons as well as the Galileo orbiter.

The Pioneer's scientific limitations weren't its only problems. Many planetary scientists feared that approval for follow-up flights to fill in the gaps might be hard to get. Others felt that a Pioneer Jupiter orbiter couldn't return photos that the public would appreciate. Some scientists felt that NASA's planetary program must continue to undertake complex technological tasks, such as the Galileo orbiter, to advance the state of the art. Others remembered that it had been as hard to get money for Pioneer Venus as it was to get money for the much more capable Voyager mission. If government would only approve a few projects, perhaps, the thinking ran, they should be as sophisticated as possible.

When the Solar System Exploration Committee first met, the factors that had earlier caused NASA to reject a new Pioneer mission still existed. Even worse, the U.S. fiscal situation had deteriorated; the dollars in the 1980 planetary budget bought half as much as



Pioneer Venus Orbiter Mission marked the last American attempt to probe our neighboring cloud-covered planet. It specialized in studying the upper atmosphere. NASA/Ames photo.

the dollars in the 1976 budget. Some scientists proposed that a series of new Pioneers might help restore the program's momentum. One committee member, Charles Barth, director of the Laboratory for Atmospheric and Space Physics at the University of Colorado, suggested a way to find out.

Barth's ultraviolet spectrometers on Mariners 6 through 9 examined the rate that the Red Planet's water broke down into hydrogen and oxygen. The results, if they represent patterns lasting eons, mean that Mars once had abundant surface water.

"Almost any question you ask about Mars involves water in some way," says Barth. "It has had an almost unbelievable effect." The river beds scarring the surface are one example. The glaciers capping the poles are another. So is the planet's color. When H_2O breaks apart, the hydrogen heads for space while the oxygen rusts the iron in the soil. Water probably helped form the clay-like soil that both the Viking landers found. Water vapor also destroys atmospheric ozone, allowing ultraviolet light to reach the ground and create peroxides — compounds rich in oxygen that some researchers believe mimicked life in Viking's biology labs.

"The role of water is as important to the climate as it is for the surface," continues Barth. "But knowing what water does is like knowing the butler did it without knowing how or why." Past missions never carried all the instruments needed to get the complete story, and they always had orbits suited for picture snapping, not water studies. "I suggested to my colleagues that we use a mission focusing on the questions surrounding Mars' water as our example of future Pioneer class missions." The committee agreed and in February 1981 asked Jim Murphy, chief of the Space Missions Branch at NASA's Ames Research Center, to assess the feasibility, design, and cost of a Pioneer Mars Orbiter Water Mission.

Barth's group, working in Boulder, Colorado, assisted by investigating the science requirements. The two basic problems — where is the water, and how does it get from place to place — became a number of specific questions for the orbiter to answer. How much of Mars' water is in the soil? How much water has the planet lost into space? What are the relative amounts of water and carbon dioxide ices in the polar caps, and how does that differ throughout the martian year? What role do dust storms have in transporting water across the globe? How does water affect the climate?

With the objectives established, the group turned to instrumentation. The mission's jack-of-all-trades was the pressure-modulated radiometer, which at 18 kilograms outweighs all the other instruments combined. It measures the infrared energy radiated by gases in the air to detect dust, water vapor, and clouds in the atmosphere. It also determines temperature and pressure both at the surface and at various heights. Another instrument, the frost detector, measures infrared light reflected from the ground. This enables it to find water and carbon dioxide frosts and ices. Two ultraviolet spectrometers that would also be included in the mission can measure reflected ultraviolet light to map the distribution of ozone.

All the instruments return their best data from close to the planet — no higher than 500 kilometers. To keep the atmosphere from dragging the spacecraft down to a blazing finale, the orbiter has to stay above 200 kilometers. Barth's group compromised on a circular orbit 300 kilometers up.

With the scientific needs established, Murphy's group at Ames began the engineering study for this new Pioneer. The basic requirements weren't too difficult compared to those of previous Mars missions — except this one had to be done for a fraction the cost. Satisfying that requirement meant modifying the design of an existing terrestrial satellite to make it an interplanetary voyager.

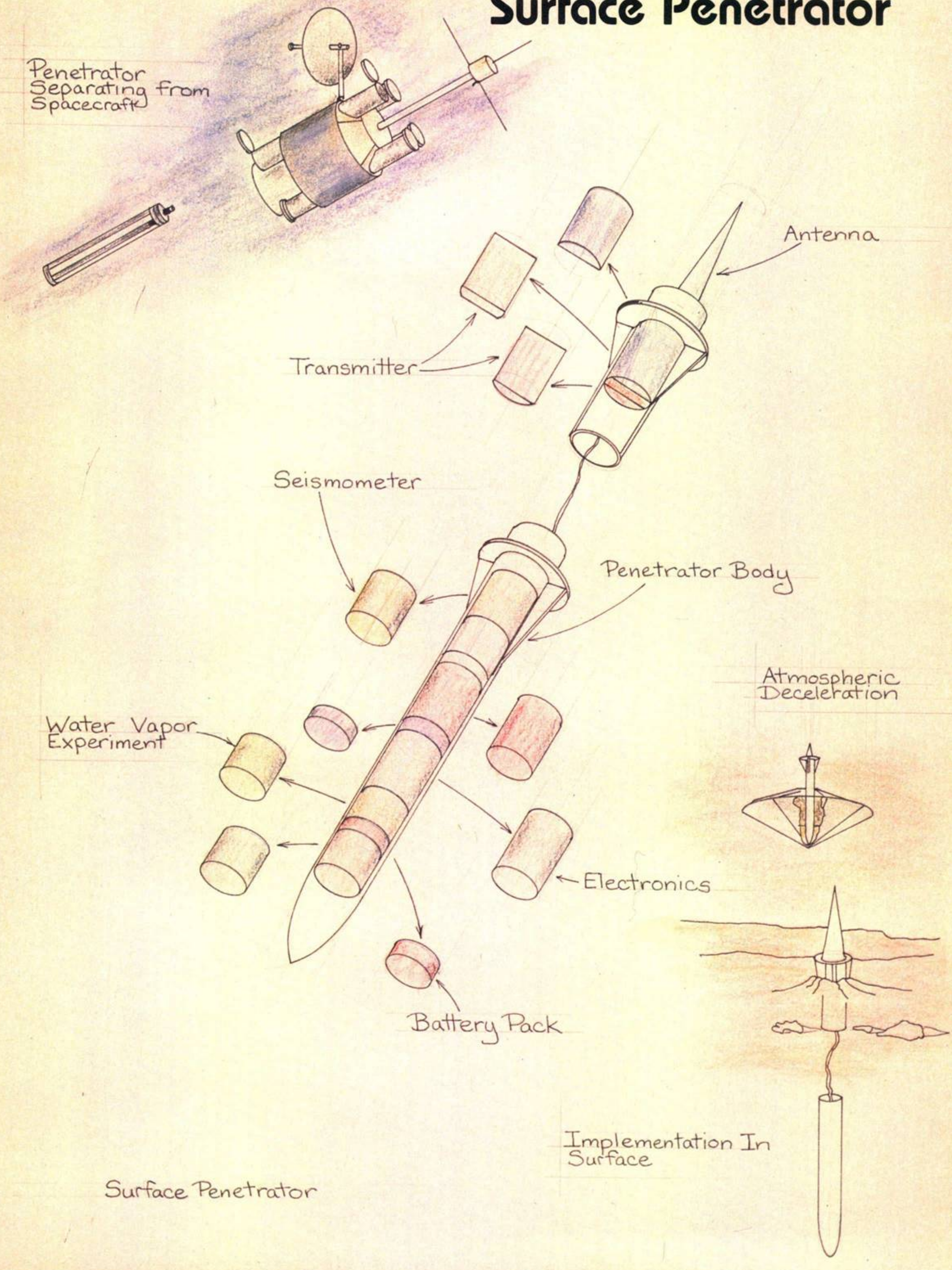
Murphy asked four companies — Hughes Aircraft, Ball Aerospace, RCA, and Martin Marietta — to check the feasibility of re-designing satellites they'd built. Three companies recommended cylinder-shaped craft while Ball Aerospace recommended something that resembled a frisbee. All four of these designs were both functional and economical and they vindicated the idea of modifying terrestrial satellites.

At $90 million Barth's mission was a bargain, and many branches of planetary science stood to benefit. Understanding how water moves across the globe requires detailed examination of the martian climate, and the orbiter would make the necessary measurements. Knowing where the water is tells biologists where martian life might congregate.

The geophysicists got a bonus not even related to the mission's primary goal. Radio tracking of the craft would reveal minute changes in the martian gravity field caused by materials of different density lying beneath the surface, and the not-quite-spherical shape of the planet. Barth's orbiter would be the first to take up the low, circular orbit around Mars needed to accurately map these changes. Geologists have very few ways to learn about the forces and materials found deep inside a planet, and gravity field mapping is one of the best.

This craft also might be the first to use radar to accurately measure terrain heights, allowing

Surface Penetrator



Penetrator Separating from Spacecraft
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Water Vapor Experiment
Electronics
Battery Pack
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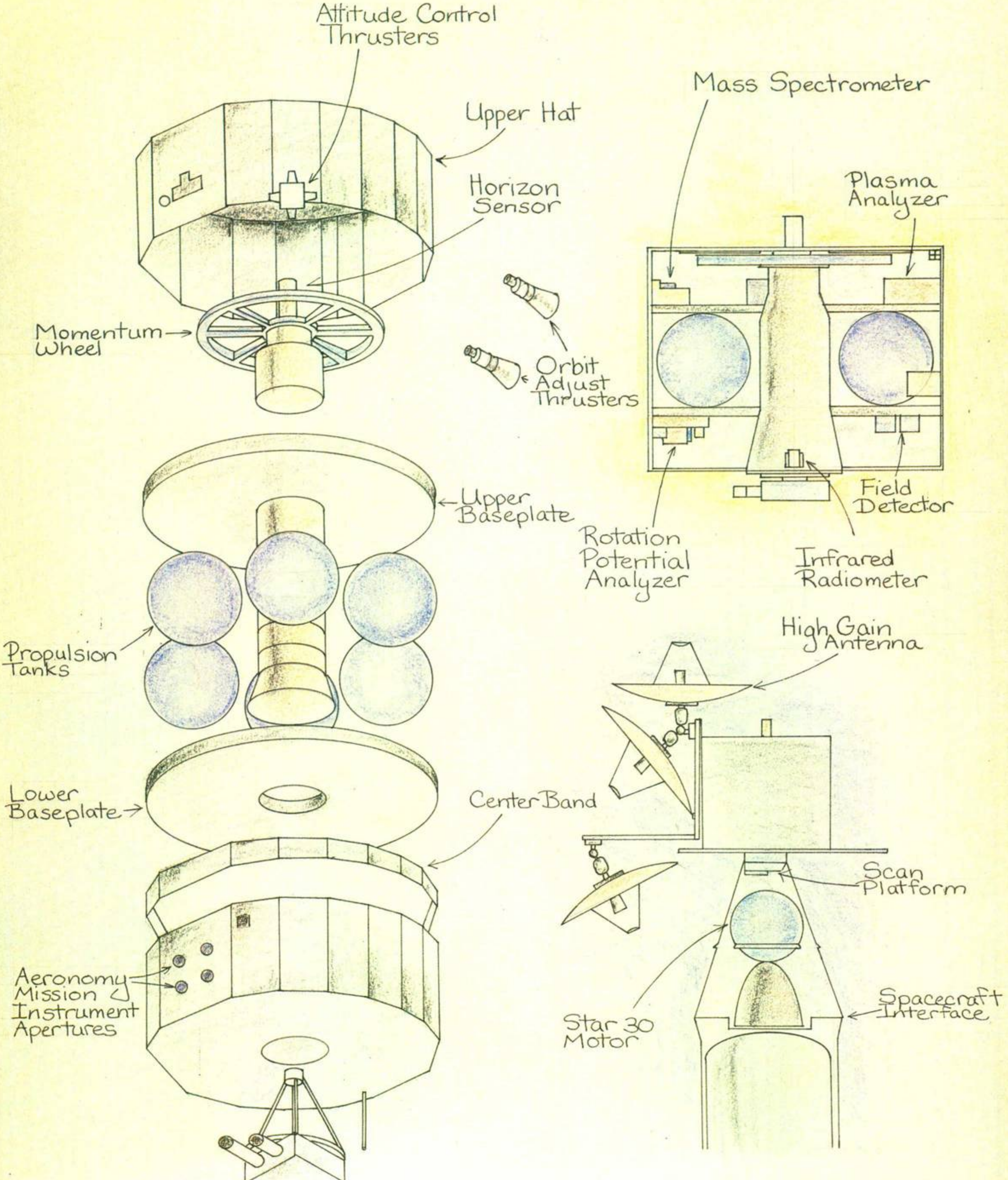
Surface Penetrator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Mars Orbiter

geophysicists to relate the information gathered on the interior to the surface features above. Currently, geologists must work with broad estimates. The peak of the volcano Olympus Mons, judged from present data, might stand anywhere between 18 and 27 kilometers high.

It isn't just the water and gravity studies that make Barth's mission attractive, for every Mars orbiter seriously considered over the last few years would conduct some of the necessary measurements. Rather, this mission takes a specific goal from a cast of a dozen or so goals planned for the big missions and makes it a star. The price is low too — and that's what this decade demands.

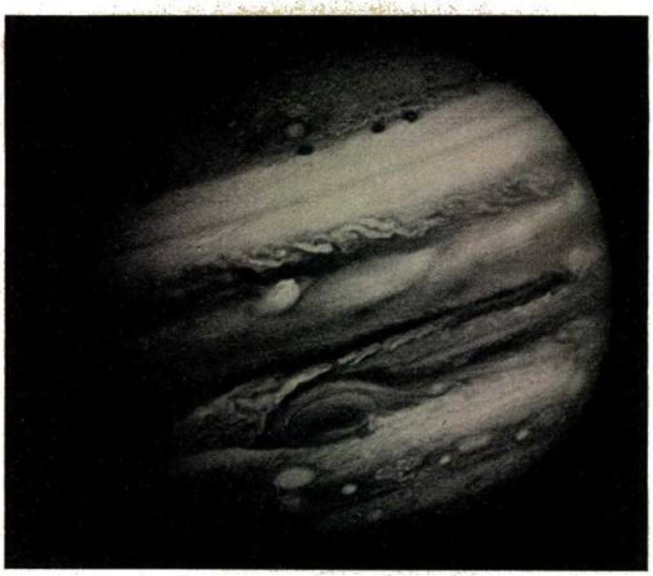
What works for one goal should work for others. The group at Ames began teaming up with other scientists to find out. The most obvious mission, because the Pioneer Venus orbiter did it at Venus, was a study of the upper martian atmosphere.

Mars' upper atmosphere holds special interest for aeronomists. Except at the poles, the Earth's magnetic field buffers the ionosphere from the solar wind. At Venus, where the Pioneer Venus orbiter studies the interaction, the only magnetic field comes from the solar wind sweeping across the ionosphere. Mars appears to be in between. A weak magnetic field generated deep within the planet probably buffers the ionosphere slightly. The Pioneer Mars orbiter could study the weak martian field and help answer the questions aeronomists ask about the Earth's ionosphere: How does the solar wind aid in the escape of gases from the atmosphere? How does the solar wind affect the ionosphere's chemistry? How much energy does the solar wind dump into the atmosphere? And how does the solar wind interact with the magnetic field?

A third Pioneer Mars mission proposed by the Ames team grows out of a late 1950s study by Sandia Laboratories on ways to deploy nuclear bombs from low-flying jets. One of the results of that study was a spike-like vehicle called a penetrator. Even when hitting the ground at hundreds of kilometers per hour, it didn't shatter. Instead, it often burrowed as deep as a ten-story building is tall. While never used for their original purpose, thousands of penetrators have been used for everything from monitoring troop movement along the Ho Chi Minh trail to measuring the electrical conductivity of Hawaiian lava flows.

Individually, no Mars-bound penetrator would match the sophistication of the twin Vikings that landed in 1976. One of these new landers barely reaches to the chin of a man and is only as wide as a one pound coffee can while each Viking was the size of a jeep.

But these needle-shaped landers have some advantages over earlier missions. They are cheap enough that a single mission could pepper as many as six across the planet. They could also be put down anywhere: inside a crater, on a canyon rim, into an ice cap, or on the flanks of a volcano. The Vikings had to land on two of the safest — and dullest — spots on Mars. And penetrators could take measurements both from instruments mounted on the antenna housing left on the surface and from instruments in the main body deep within the soil. All the Viking instruments were above ground.



Voyager I snapped this picture more than two years ago. At the time it was the best image received from Jupiter. A new class of Jupiter probes would once again give us exciting revelations about the planets. NASA/JPL photo.

"There are some studies you can't do well from just one or two landers regardless of their sophistication," says Ray Reynolds, a planetary researcher at Ames and a long-time penetrator advocate. "Seismology is one. Quakes can tell a geophysicist a great deal about a planet, like what are the sizes of crust, mantle, and core and what areas of the planet are still geologically active. To be sure of their results, though, researchers must have measurements from several stations.

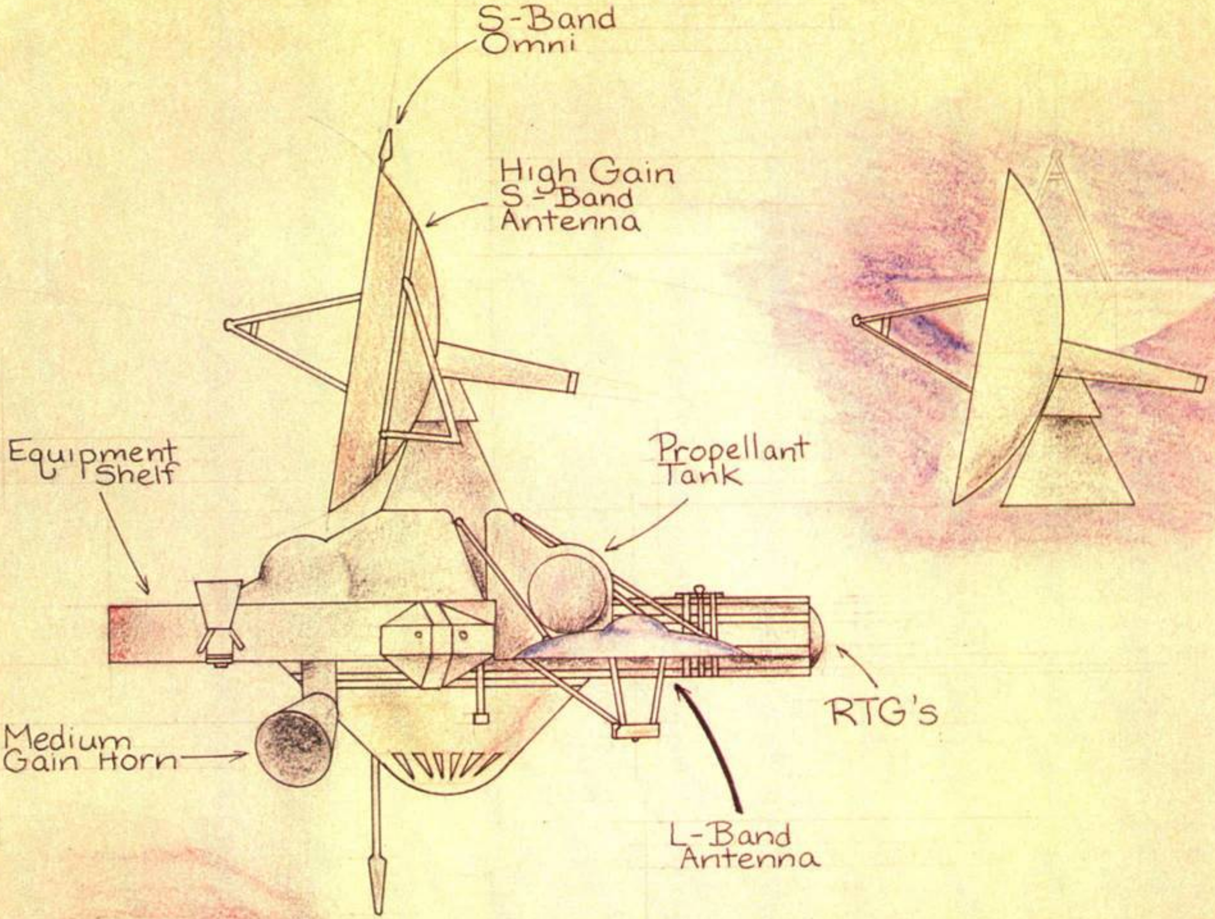
"Meteorology also requires data from a number of sites. It's virtually impossible to really understand the dynamics of an atmosphere without pressure, temperature, humidity, and wind information from across the planet."

Although network studies are the most productive use of penetrators, each one could individually reconnoiter its impact site with cameras. Unfortunately, they would show us only a rabbit's-eye view, since the camera could be only inches off the ground. The researchers aren't sure they'd want to trade an accelerometer, which records the nature of the soil the penetrator impacted, or an alpha-proton-X-ray spectrometer, which analyzes the soil's composition, for an ankle-high panorama.

Any composition studies the penetrators made would complement the studies of the last Pioneer Mars project suggested by the Ames team. Despite some Earth-based infrared spectra, educated guesses, and soil studies from the Viking landers, we know virtually nothing about the chemistry of the martian surface. We aren't even sure what minerals combine to produce that rusty color. Murphy's group proposes that NASA send a Pioneer orbiter to find out.

In theory, any number of techniques — from the measurement of radiated X-rays to the measurement of reflected ultraviolet light — can reveal soil composition to an overhead craft. In practice only two techniques are serious candidates.

The first, infrared spectroscopy, records the spectrum of near-infrared light reflected from the surface. Because different materials absorb and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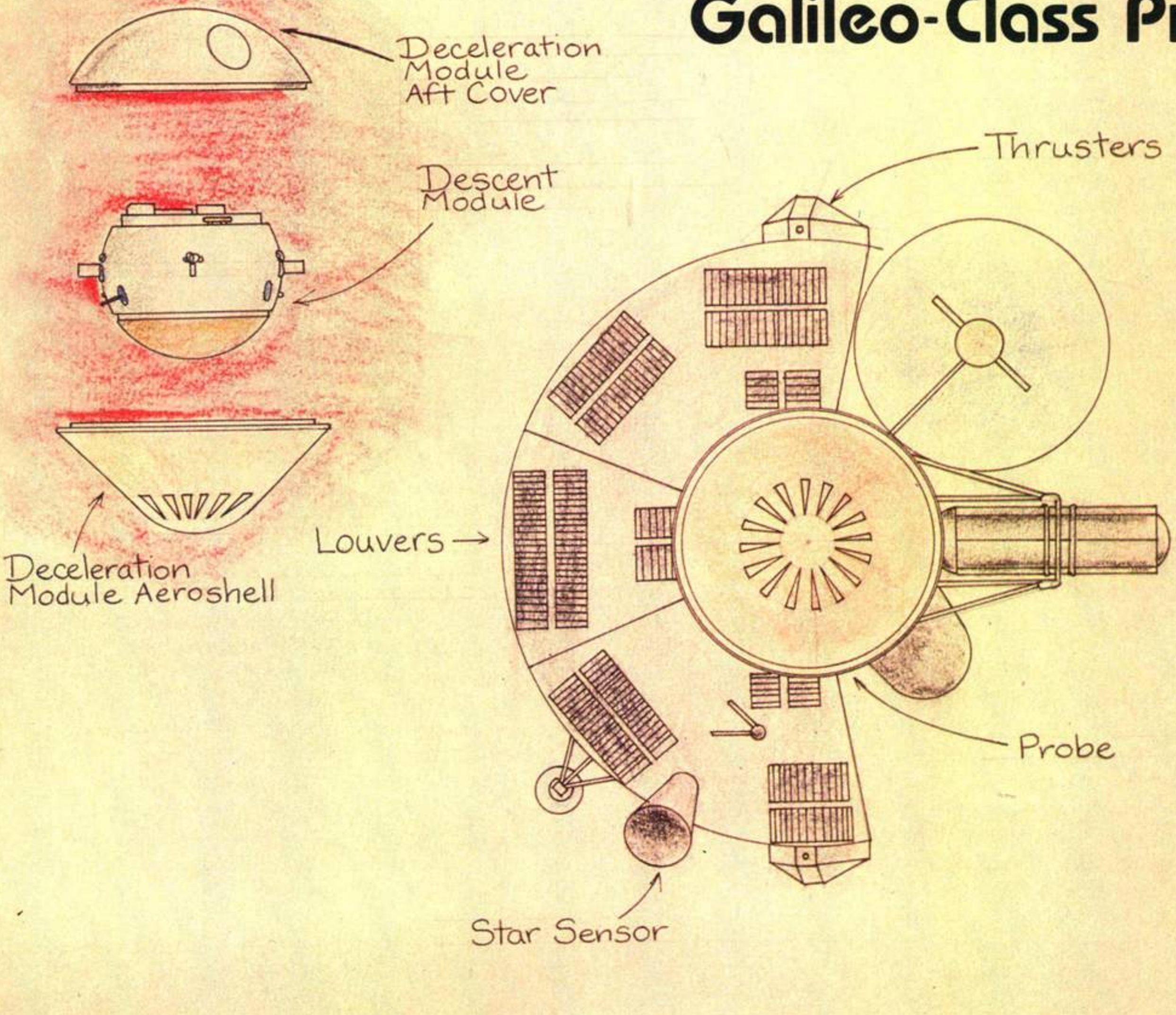
Deceleration Module Aft Cover
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reflect infrared light differently, geologists use this experiment to determine what minerals lie on the surface. With this information in hand, they can deduce the mineral composition below the surface. Basalts, for example, would indicate a mixture of feldspars, pyroxene, and olivine. Clays, on the other hand, would suggest a mixture of hydrous silicates of aluminum with impurities such as hematite and limonite that give them their colors.

The other technique uses gamma-ray spectroscopy to record gamma radiation produced by different elements as they decay naturally, or as they are are struck by cosmic rays. The resulting information reveals the elements and their abundance in an area. From the elemental recipe list, geologists can usually determine the type of rock examined.

Together, a series of Pioneer Mars spacecraft can match the capabilities of a single Galileo type spacecraft for about the same cost. The big mission orbiter would research more areas at once, while the Pioneers spread the same research — and costs — over eight years or so. Both approaches produce equivalent results, though a Galileo class orbiter would take high resolution photographs where Viking could only spot a martian football stadium.

But high-resolution photography is down in importance on most scientist's wish lists. According to Ames's Reynolds: "With everything else more or less equal, I'd prefer a series of small Mars missions to a single large one because we can explore questions raised by one mission with the next spacecraft."

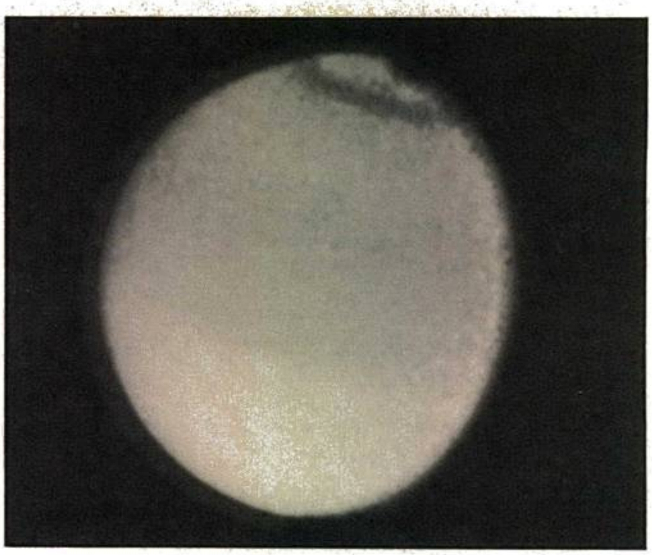
Mars is not the only world where focused Pioneer missions offer an attractive alternative. Jim French at the Jet Propulsion Laboratory has been studying low cost orbiters to examine the composition of the lunar crust. John Neihoff of Science Applications, Inc., has dusted off old studies for a Mercury orbiter to explore that planet's surface composition and magnetic field. Jim Pollack at Ames wants to send a probe into Venus' atmosphere to answer questions not addressed by Pioneer Venus.

The outer solar system is the least likely area for the low cost approach. The long communications line, the travel time, and the distance from the Sun's heat and light conspire to make even the cheapest mission past Mars as expensive as the costliest inner planet Pioneer. But by copying the design of the Galileo atmospheric probe and mating it with a carrier craft proposed by Hughes Aircraft, the Ames team found a way to fit flights to Saturn and beyond into a relatively small budget.

The Voyagers revealed much about the atmospheres of the planets they visited. They photographed cloud movements, measured composition, and determined energy balances. However, their results are difficult to interpret, and only apply to the small portion of the atmosphere above the upper-most cloud deck. The next step, which Galileo will do for Jupiter, is to carry instruments deep into each atmosphere.

Based on the Ames team's results, the next flight to Saturn might follow this sequence:

One hundred days before encounter, the carrier releases the probe — a spherical instrument package about three feet across encased in a heat shield — on a trajectory that will lead it into Saturn's atmosphere. The carrier then re-targets itself to pass safely overhead. Three months later, the probe crosses the outer-most edge of the rings. A little while later, it is a fireball streaking across the saturnian sky. Two minutes after that, the heat shield falls away and a parachute pops out.



Voyager II images of Titan posed many new questions, but we won't get a closer look at this smog-covered moon for a long time. When we do, planetary scientists hope to also sample the atmosphere. NASA/JPL photo.

As it drops at 200 kilometers an hour, the probe measures the characteristics of the atmosphere in detail that could never be provided by a remote spacecraft. What chemicals lace the air? How strong are the winds? Is there lightning? How thick are the ammonia clouds and the water clouds beneath them? What is the ratio of energy coming from the Sun and from Saturn's interior? The temperature of the air continues to rise and the battery grows weaker as the probe continues to fall. From somewhere below the water clouds, the last bit of data makes its way to the carrier for relay to Earth.

The atmospheric probe's information is just part of the scientific return from these Pioneer missions. "When we first started looking into the uses for the probe carrier beyond relaying the probe's data," says Jeff Cuzzi, an expert at Ames on Saturn's moons and rings, "we didn't think we'd find much that Voyager hadn't done better. We hadn't realized how much technology had advanced. Instruments that weren't practical when Voyager flew are candidates for this mission. Although a well-instrumented probe carrier on a relatively brief pass through the system couldn't match the range of Voyager's investigations, it could still focus on our most pressing questions about each of the outer planet systems." At Saturn those questions are about Titan and the rings. Both received intense study from the Voyagers, and both have yet to reveal important facts about themselves.

Titan kept its secrets better, but what the Voyagers did learn tantalizes scientists. In size and density, this moon resembles the icy jovian satellites Ganymede and Callisto. But unlike those worlds, Titan has a thick atmosphere of nitrogen and methane polluted with an orange smog that hid the moon's surface from the cameras of Voyager. Over eons, particles of the smog have slowly settled onto the ices of the planet. By now this may have accumulated to depths that bury hills and perhaps small mountains — if there is a solid surface. Titan's surface temperature hovers at the triple point of methane where this substance, like water on the warmer Earth, can slip easily from gas to liquid to solid and back again. Methane rains may wash the smog particles off methane hills and into methane oceans.

The carrier couldn't do much to improve our knowledge of Titan's atmosphere — but a probe could. Clouds, fog, and methane rains permitting, the probe could take pictures as it dropped toward the surface. However, the carrier will have the major study of the surface to itself. An on-board millimeter-microwave infrared spectrometer will tell geologists whether smog particles, ice, or liquid methane covers a particular region. A radar unit will map almost a tenth of Titan during the six minutes of its closest approach to that moon.

The Voyagers collected more information about Saturn's rings than Titan's surface. They photographed them, passed their radio waves through them, and watched the twinkle of a star's light as it passed behind them. Despite all this, the surface and behavior of the rings is more of a mystery today than it was before the Voyagers passed by. The carrier couldn't magically answer our questions in a single pass through the saturnian system, but it could tackle the three key problems: How are the ring particles distributed? What are their sizes? And what are they made of? The spacecraft would reflect its radiowaves off the rings and to the Earth to measure distribution of the sizes. Voyager couldn't do this because of the ring-Earth angle. The millimeter-microwave spectrometer would study the size and interior composition of the particles. And a third instrument — an infrared spectrometer similar to the one proposed for Mars orbit — will determine the composition of the particles' surfaces.

While the carrier concentrates on Titan and the rings, it also can glance at other targets in the saturnian system. The millimeter-microwave spectrometer will peer through Saturn's clouds to probe the forces creating its weather. The infrared spectrometer can map the distribution of substances on the surfaces of the moons. Other instruments will repeat studies made by the Voyagers. The cameras will look for changes in the atmosphere of Saturn and Titan and in the ring structure. Those regions of the moons that the Voyagers saw only at a great distance would be photographed as the carrier's trajectory permits. But there won't be the free-for-all snapping there was with Voyager, and the carrier would record only a tenth as many photos.

Even a year and a half ago, the idea of a Pioneer mission to the sixth world would have been laughed at by all but a few members of the planetary community. Today it is acceptable and officially approved. Last fall, the Solar System Exploration Committee included not only this project but almost every other one described in this article in its plans for further study.

"We found," says Murphy, "that the Pioneers' problem wasn't *their limited capability*. Even a low cost craft can do impressive things with today's technology. The high cost comes when everyone

the little big missions

While the new Pioneer spacecraft would cut the price of planetary exploration by reducing each mission to its bare bones, a team of engineers at NASA's Jet Propulsion Laboratory has put forward a concept for a more capable spacecraft — the Mariner Mark II. If JPL's plans work out, the new series of Mariners will have the pizzazz and public appeal of the Voyagers and Galileo at a fraction their cost. To do this, JPL plans to make use of an ancient economic maxim: anything is cheaper by the dozen.

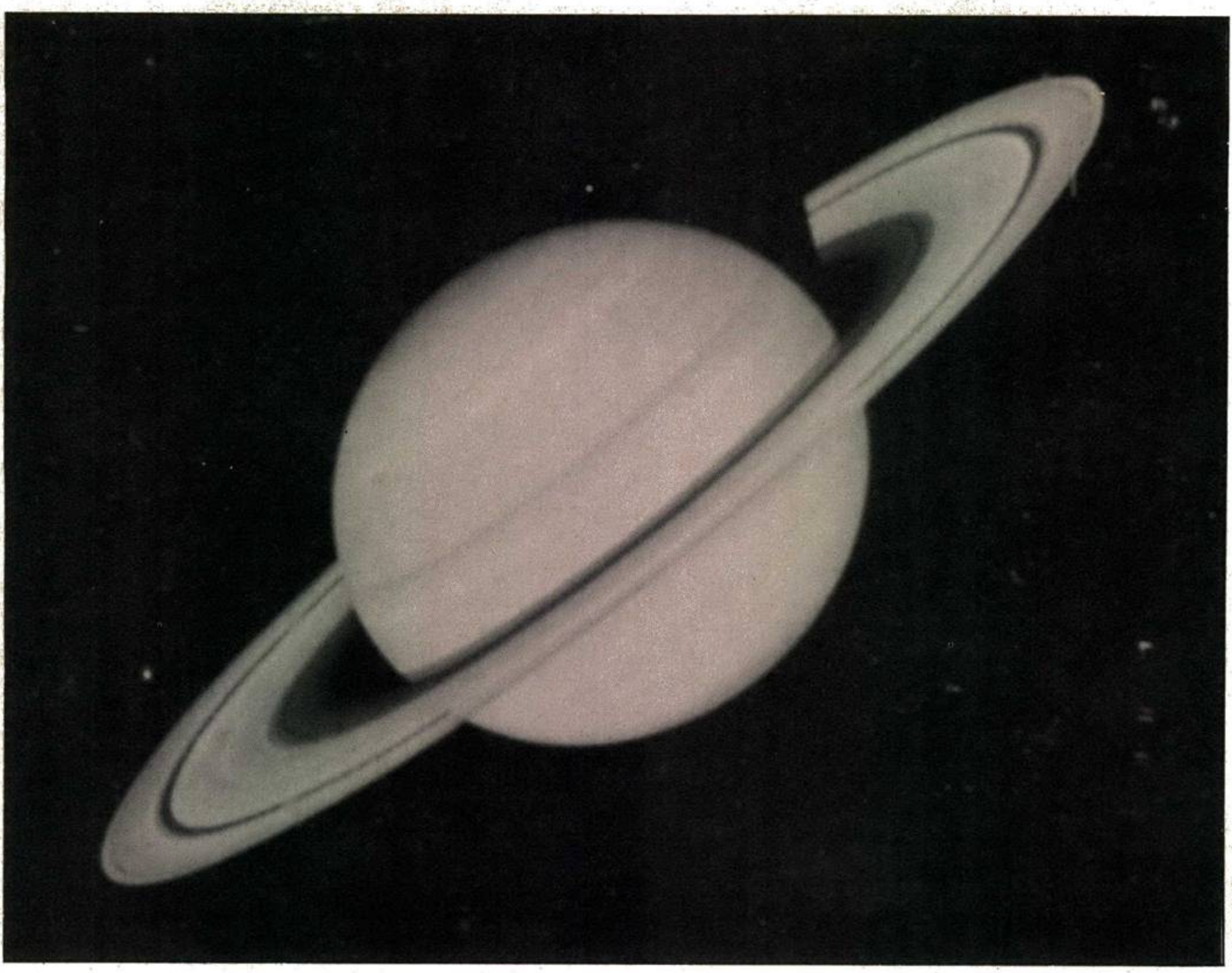
It's the cost of designing a spacecraft that skyrockets a mission's price. The nuts, bolts, and electronic chips of a craft cost peanuts by comparison. With the old Mariners — the last of which left Earth in 1973 bound for Venus and Mercury — NASA held down the cost of each mission by borrowing as much as 80% of the previous mission's design. For the last few missions, the inheritance has fallen to 35% for Voyager and Galileo and to 10% for Viking.

To keep the Mariner Mark II missions in the $150 to $300 million range, the space agency has to fly a sequence of four to six spacecraft so each can make maximum use of the work that went into its predecessor. A Saturn orbiter might follow a comet rendezvous craft so it could use already designed communications, computer, and attitude control systems. The money saved would leave enough to pay for the design of components needed at the ringed planet. JPL's engineers believe they could reduce spacecraft costs by up to 60% by flying the Mark IIs as a series — especially if they stockpile critical electronic components at the beginning of the series.

While these missions borrow heavily from each other, they won't borrow much from projects that flew before them. "The planetary program always has been at the forefront of technological development," says Don Rea, JPL's assistant lab director for technology and space program development. "We think the new Mariners will continue that tradition." In the past, new developments increased the capabilities of the spacecraft. Now JPL wants to push technology to keep the current level of capability, but at a lower cost. Future craft, for instance, might carry computers that process much of the data gathered on board so the amount of information that must be sent home could drop by two-thirds or more. The overall cost of the mission would drop, because we could use less expensive communications and power systems.

No absolute boundary separates the Mariner Mark IIs from the Pioneers. Both programs depend on design inheritance to reduce costs, but the Mariners more so. They also have different objectives. A Pioneer mission to Saturn, for example, might concentrate on the moon Titan and give the other moons, the rings, and the planet itself only cursory looks during its flyby. A Mariner mission to Saturn might orbit the planet for detailed studies of the entire system.

The Solar System Exploration Committee, formed by NASA to recommend a new program of planetary exploration, suggested that the agency use both approaches. The cheaper Pioneers could carry out the simpler and more focused planetary missions, while the more capable Mariners could take on the difficult and exciting exploration of comets, asteroids, the Saturn system, and Pluto.


NASA/JPL photo.

Saturn was closely scrutinized by Voyager, but few funds remain for data study. The next U.S. Saturn mission lies far in the future.

wants to do everything on every mission. Pioneers perform best for focused studies, and the Galileos for sophisticated, wide-ranging explorations. I wouldn't recommend a low cost project for a mission to a comet, an asteroid, or the moons of Jupiter. I would recommend it to study a magnetosphere, the composition of a world, or the atmosphere of a planet."

The committee agrees with Murphy's assessment. Its members plan to recommmend a mixed program with the Pioneers used to provide stability, and to quickly get data returning from the planets once again. A more capable and more expensive class of missions, the Mariner Mark IIs, under study at NASA's Jet Propulsion Laboratory, will take on the more glamorous exploratory missions to the comets, the asteroids, and the outer planets. The committee also intends to include plans for one really large mission— perhaps a $2 billion project to return rock and soil samples from Mars — in its recommendations. "We feel," says Masursky, "this mixture would give NASA a stable and exciting planetary program that requires only moderate funding levels."

The first of the new Pioneers might be launched late this decade. In the meantime, you'll see at least two Pioneer class missions from the Europeans. In 1985, the European Space Agency's Giotto will leave for the only close pass at the heart of Halley's Comet. A year later their Solar Polar craft will head for Jupiter to use the giant planet's gravity to throw it high over the Sun's poles. Two years later Kepler, a tentative mission to Mars, may enter martian orbit to carry out ionosphere and weather studies. About the same time other nations like the Japanese should start launching their own small scale missions.

"The solar system is incredibly vast, and there's an equally vast amount of research that still can be done by focused missions," said Larry Colin, Space Science Division chief at Ames. As project scientist for both the Galileo atmospheric probe and Pioneer Venus, he's worked on both the large and small scale missions. "Pioneer-like projects are the best that other nations, except the Soviet Union, can technologically do or afford. For our nation, they are a way to give our planetary exploration the stability it so desperately needs. When politics and budgets permit, we'll supplement the small projects with the big ones that have made our program so successful and unique."

Van Kane is a freelance writer in the San Francisco Bay area and a frequent contributor to AstroNews.

Topography
# of the
Terrestrial Planets

by Michael Kobrick

Topographic maps of Venus, Earth, and Mars offer new insights into the three rocky planets.

Can you imagine trying to identify Michelangelo's statue of David by throwing basketballs at it — and measuring which way they bounce off? You might be able to tell the statue's overall size and rough shape, but you'd sure miss a lot of the details. Well, that's how planetologists studying the surface of Venus feel as they pursue the frustrating task of trying to glean fine detail from a set of relatively coarse measurements — radar beams bounced off the surface.

The radar measurements at Venus are provided by an instrument on board the Pioneer Venus Orbiter, launched in May 1978, and now in its fourth year in orbit about our cloud-covered sister planet. Since the visible and infrared wavelengths ordinarily used for imaging cannot penetrate the clouds, the Pioneer instrument designers turned to radio waves — the only electromagnetic waves that can pass through the atmosphere relatively unaltered and provide direct information about the surface.

The instrument is called the Pioneer Radar Mapper, a device that beams a short burst of radio waves toward the surface and counts the microseconds until an echo, or reflection, is detected. Since we know exactly how fast the waves travel (the speed of light), we can calculate how far above the venusian terrain the spacecraft is flying at any one time. We also know from Earth-based tracking (again using radio signals) where the orbiter is located. When we combine these pieces of information, we can measure the elevation of the terrain.

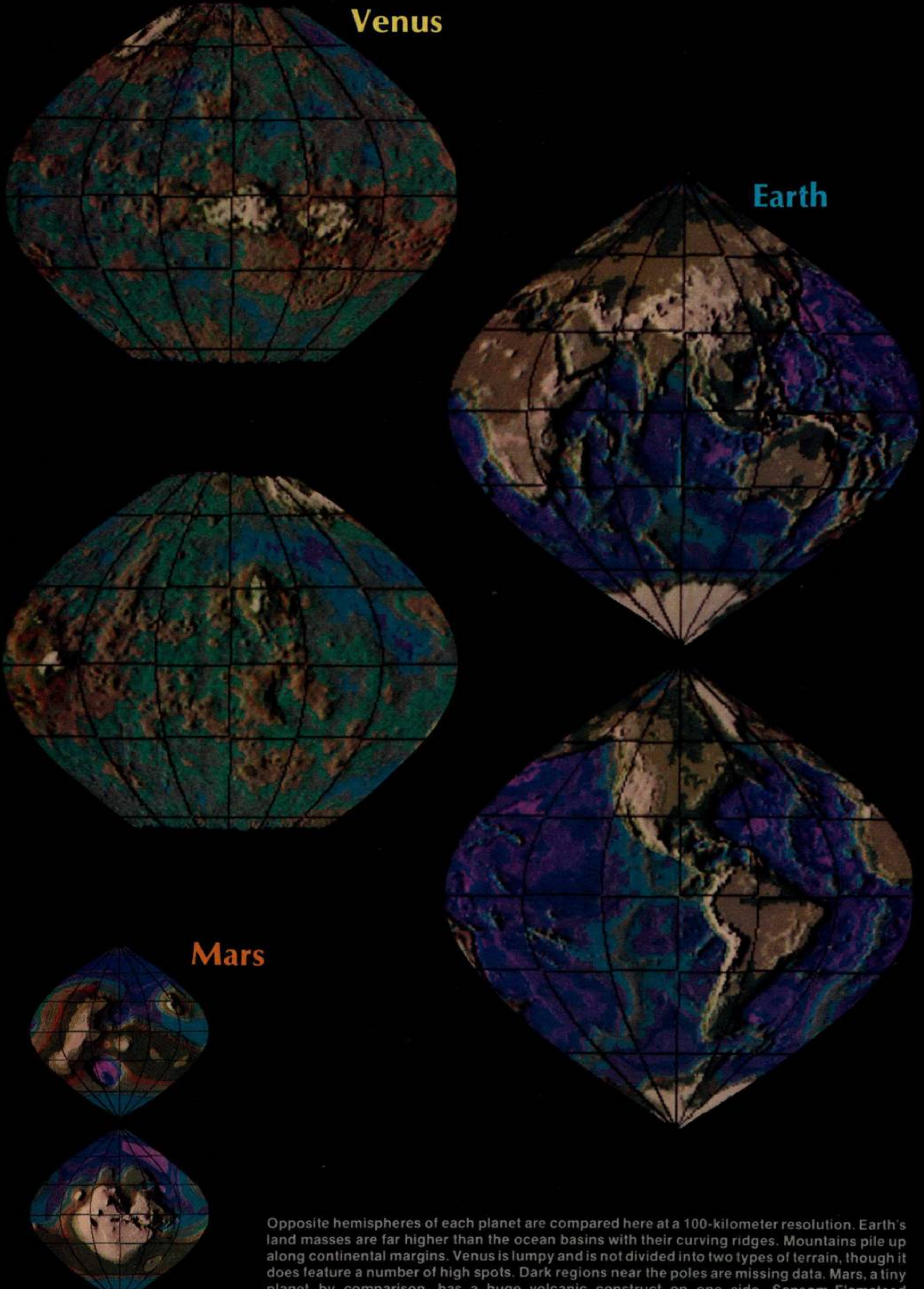
Headed by Gordon Pettengill of MIT, the radar team combined several hundred orbits worth of data to produce a topographic map of 92% of the planet's surface. Only the north and south poles are missing, because Pioneer's orbital tilt prevents it from passing over these areas. Their map has been computer-processed to produce shaded relief maps, color-coded elevation maps, and even stereo pairs for three-dimensional viewing (see "A World Revealed: Venus by Radar," ASTRONOMY, March 1981).

These maps are certainly pretty, even spectacular, but what do they tell us about Venus? At first glance, they seem to show that Venus is not very much like Mars or the Earth. Our own planet has a broad distribution of elevations with a standard deviation of almost 2.5 kilometers about the mean, while Venus varies by a little more than a kilometer. More importantly, we know that the topography of the Earth is divided into two provinces: broad, flat plateaus with steeply sloping edges which we call continents, and the topographically rougher seafloor.

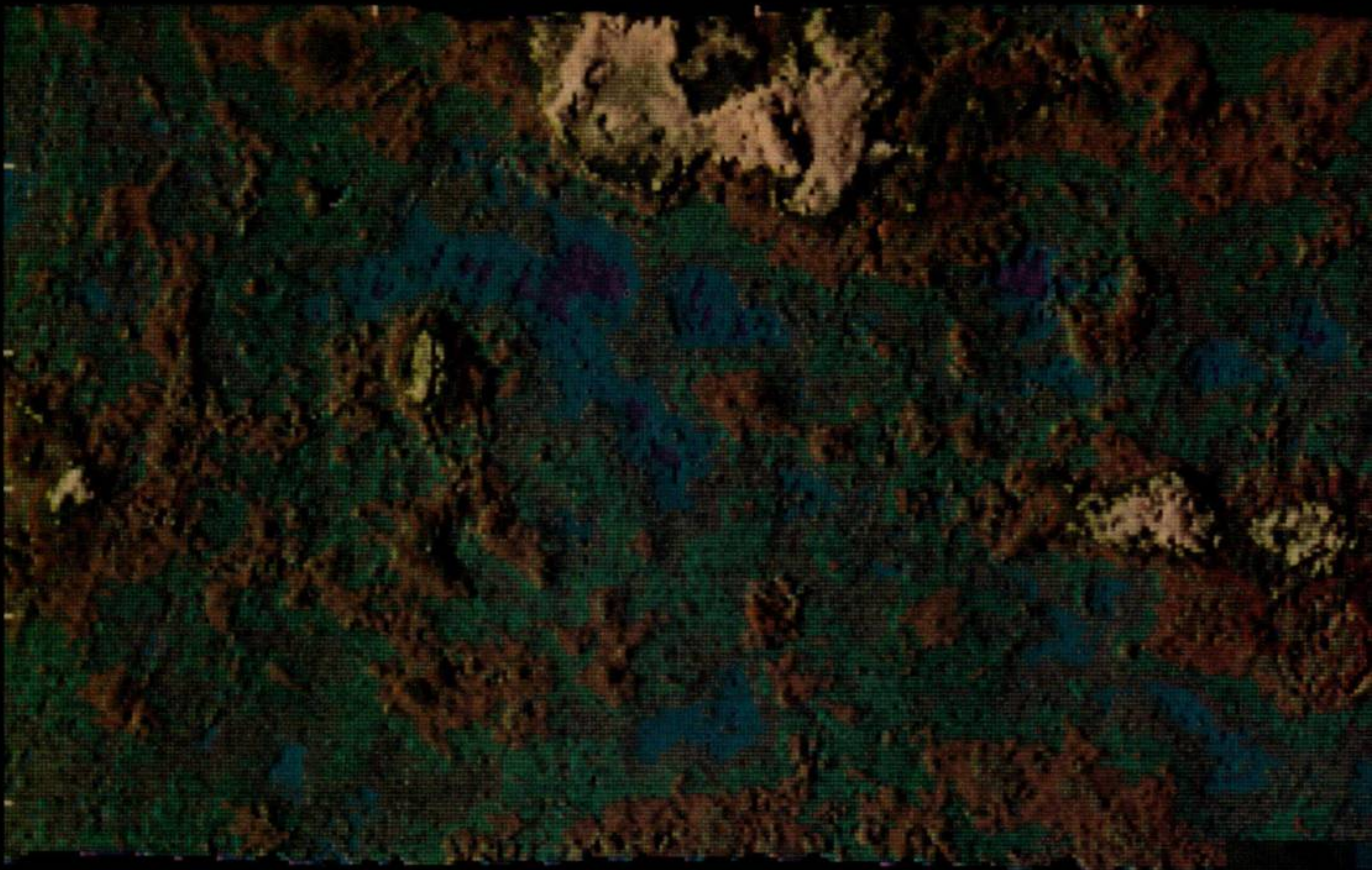
With the exception of the small northern plateau named Ishtar Terra, there is nothing on Venus analogous to terrestrial continents. Most of the surface is covered by what has been dubbed "rolling upland" terrain, a gently varying plain possibly similar to the cratered highlands on the Moon or Mars. Unfortunately, the resolution of the Pioneer radar data does not show enough fine detail to detect individual craters — if, indeed, they do exist.

Since Venus possesses about the same mass, radius and, as far as we know, chemical composition as Earth, we might expect the solid bodies and surfaces of the two planets to be similar. The Earth is a very dynamic planet, with surface topography dominated by the results of plate tectonics — the movement of the large plates of matter that make up the lithosphere, the outer layer of our planet's crust. Where plates collide, we have faults and earthquakes. When one plate slides in underneath another, a process called *subduction*, trenches and eventually volcanos form when the subducted plate melts and bubbles to the surface. The west coast of the United States is a good example, where the collision of the North American, Pacific and a few smaller plates causes the San Andreas Fault and the Cascade volcanos, including Mount Saint Helens.

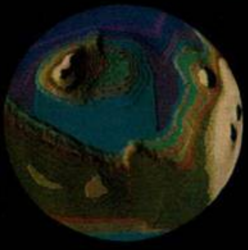
If Venus has few or no continents, does it also lack faults, trenches and volcanos? We know these exist on Earth because we can study them here in great detail. If they exist on Venus, would the Pioneer radar data show them? To try to answer this question, Steve Saunders, Walt Brown and I gathered topographic data for each of the terrestrial planets — Earth, Venus, and Mars — and processed it in a fashion similar to the Pioneer radar data. Information for Earth was compiled by the Rand Corporation and Scripps Institute of Oceanography from topographic and bathymetric maps. Mars data came from various spacecraft instruments and Earth-based radar mapping, and was compiled by the U.S. Geological

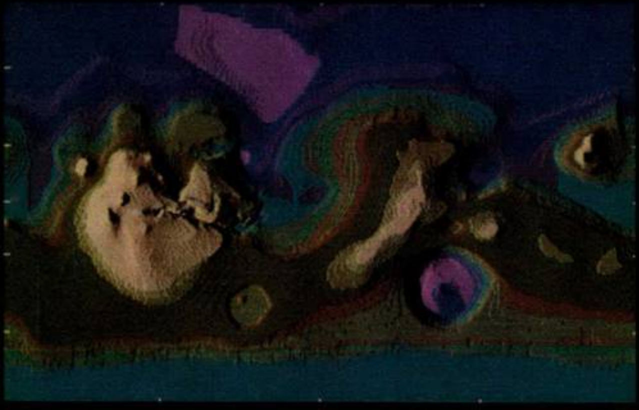


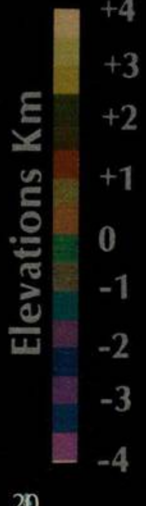
Opposite hemispheres of each planet are compared here at a 100-kilometer resolution. Earth's land masses are far higher than the ocean basins with their curving ridges. Mountains pile up along continental margins. Venus is lumpy and is not divided into two types of terrain, though it does feature a number of high spots. Dark regions near the poles are missing data. Mars, a tiny planet by comparison, has a huge volcanic construct on one side. Sansom-Flamsteed projections generated at JPL.



Mars



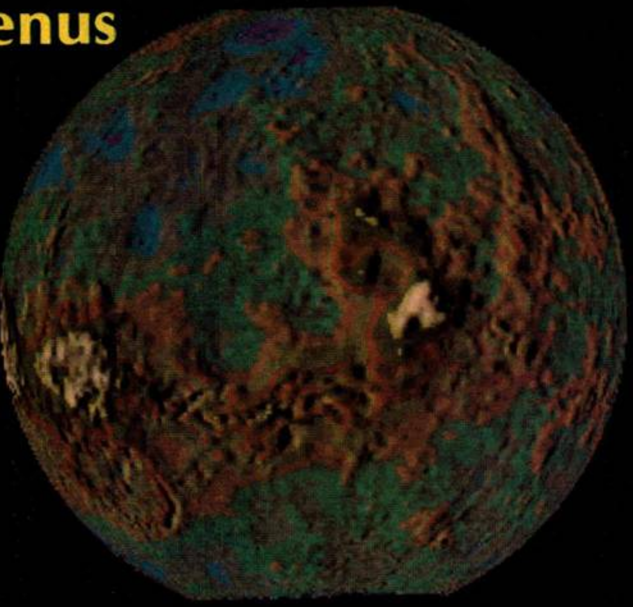




The greatest feature on Mars is its mighty Tharsis bulge — with Arsia, Pavonis, and Ascreus Mons forming a line of large volcanos. Massive Olympus Mons is the white bump just above and left of the first three. Vallis Marineris is the thin cleft running right from the bulge. Hellas basin, probably an ancient impact scar, is the circular depression at lower right. See the July 1981 issue for more on Mars.

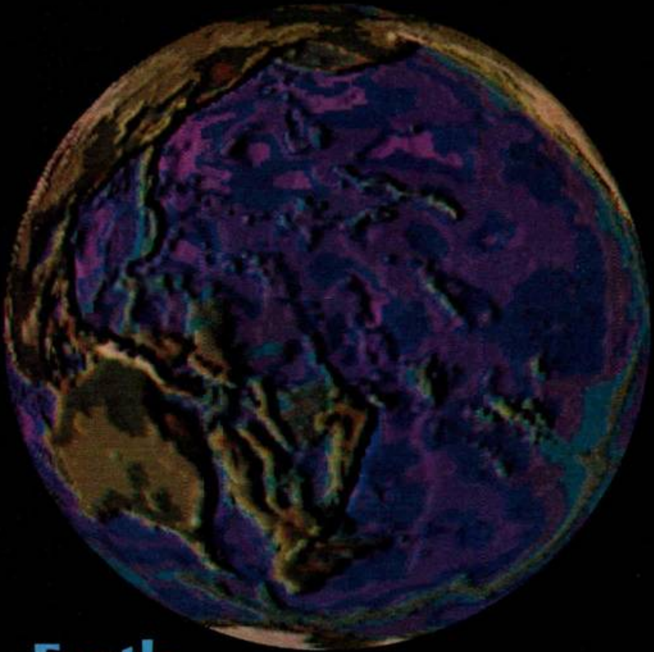
Earth's geography is far more familiar — large fairly flat continents rise above oceanic plains. Ocean bottoms have central ridges, the site of seafloor spreading. The vast bulges of the Himalaya Mountains and the ridges of mountains on the west coast of the Americas mark colliding plates of planetary crust.

Venus



Venus' principal high spot is Ishtar Terra, at top center. The Maxwell Montes are the highest points on Ishtar. Aphrodite Terra's twin highs mark the middle right, and Beta Regio is the abrupt peak at middle left. Low regions are Atalanta Planitia, upper right, and Sedna Planitia, upper middle. See the March 1981 issue for more on Venus.

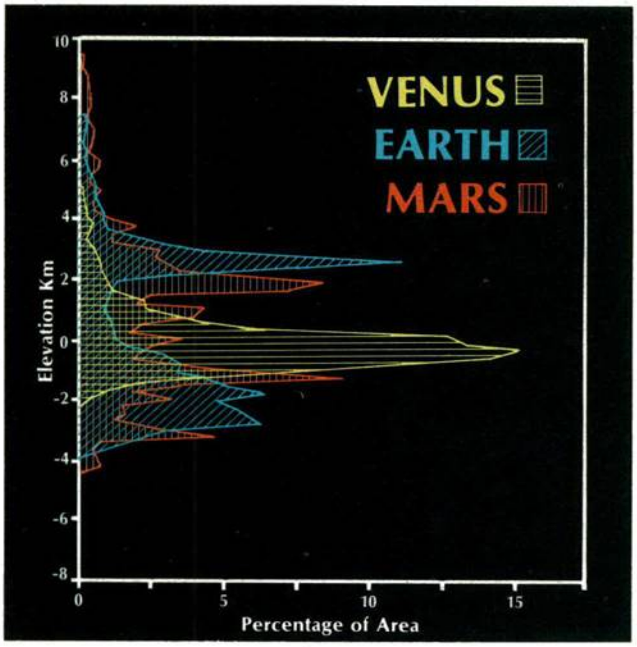
Mercator and orthographic projections generated at JPL.



Earth

Survey.

The resulting pictures of the Earth clearly show separate continental and seafloor provinces. It's also quite easy to see the long sinuous oceanic rises where material wells up from the interior and forms mountain chains. The lateral spreading of these mountains provides the driving force for plate tectonics. Trenches — where plates collide and are subducted — are more difficult to recognize. They are generally located near "island arcs," as in the western Pacific, and are usually less than 100 kilometers wide. Since this is very near the limit of the Pioneer radar resolution, analogous features on Venus might be impossible to recognize.



The histograms of elevation also show differences between the terrestrial planets. Mars' topography is chaotically spread over a broad range of altitudes. Venus is, by comparison, very smoothly distributed across a narrow range of values — a world that is smooth on a planetwide scale. Earth's elevations show a bimodal distribution — with continents and oceans sharply separated. Earth is an active world with plate tectonics.

Ray Arvidson and his colleagues at Washington University have looked more closely at topographic data for the northern Pacific Ocean, and have used it to simulate conditions on Venus by carefully correcting for the higher temperature and lack of oceanic loading. They conclude that the seafloor rises and most other plate tectonics features should be visible in the Pioneer data — if they exist.

The simulation of radar altimetry data is tricky, but an obvious method would be to take an elevation map of a known region and "smear it out" with low pass filters similar to those used in imaging processing. This averages elevation over large areas and "smooths" the resulting topography. Radars often seem to have this effect on elevation measurements. However, our experience with the Apollo 17 lunar orbiting radar and with radar measurements of Mars obtained at the Goldstone tracking station show that profiles across narrow valleys and craters frequently look as if they were high-pass filtered, that is, valleys and craters appear much narrower with much steeper edges than they really possess. This happens because radar altimeters generally detect the point of the terrain closest to the spacecraft. If that point happens to be a mountain or crater wall off to the side, the radar "thinks" it's seeing the ground directly underneath and records it as such. When the return from the trench or crater bottom becomes strong enough to trigger the automatic tracking mechanism, the topographic measurement may suddenly "jump" from the top of the wall to the floor. The resulting profile looks like a narrow well with vertical sides, a feature with all the characteristics of a data dropout which many data processing algorithms (and humans) are trained to ignore!

If Arvidson is correct, however, and Pioneer radar could have detected Earth-like plate features on Venus, then it may be that Venus is more like Mars than it is like Earth. Although Mars is a geologically active planet (see "Mars After Five Years," ASTRONOMY, July 1981), with rift valleys and volcanos, it shows no evidence of plate motion. In fact, the great volcanic plateau called Tharsis (centered on the equator at 90 degrees west longitude and containing Olympus Mons, the highest mountain in the solar system) has grown so large mainly because it is sitting still over a "hot spot" in the interior, its source of magma.

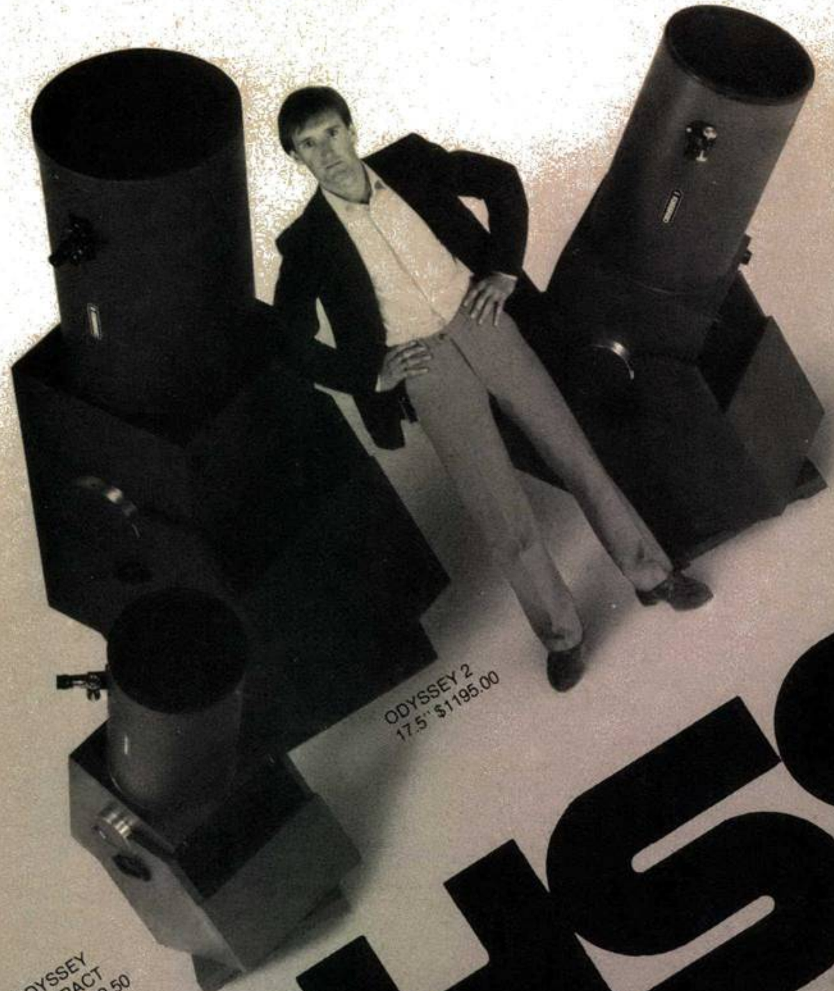
The Hawaiian Islands on Earth are the result of a comparable phenomenon in some respects, but there the northwest motion of the Pacific plate over the "hot spot" has created a chain of islands which will eventually erode away — instead of the giant volcanic construct seen on Mars.

Some researchers have tried to explain the differences between the surfaces of Venus and Earth by speculating that a combination of higher temperature and lack of water caused a deepening of the layer where basaltic rocks undergo a phase transition to a more dense state. One effect of this would have been that much more light crustal material floated to the surface on Venus than it did on Earth, building a thicker crust which eventually choked off and stopped plate motions.

Unfortunately, definite answers to all these questions must wait until we have images of Venus comparable to those we have of Mars from the Mariner and Viking missions. The recently canceled Venus Orbiting Imaging Radar (VOIR) could have provided radar images of the entire surface showing the same amount of detail that we now have for Mars. A version of its primary instrument, called a synthetic aperture radar, was part of the payload for the second flight of the Space Shuttle *Columbia* and demonstrated the potential of radar imaging for geological exploration and resource mapping of the Earth (see "Not Rain, or Snow, or Dark of Night Stops SIR-A" ASTRONOMY AstroNews, February 1982).

As this is written, however, the entire planetary exploration program is in jeopardy. (See "The Planets or Bust," this issue.) Unless there is a major change in the direction of the American space effort, answers to many questions about the planets will remain as hidden as the surface of Venus at least until the end of this century.

Michael Kobrick is a member of the Radar Remote Sensing Team at the Jet Propulsion Laboratory in Pasadena, California.



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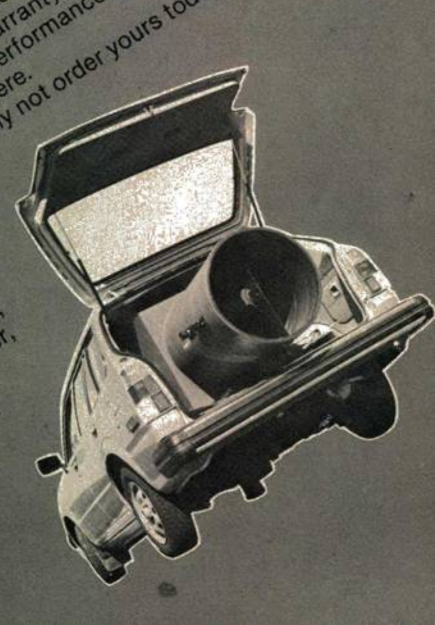


ASTRONOMY FORUM

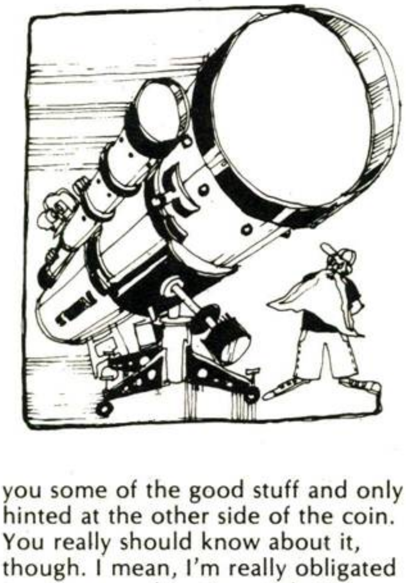
Amateur Astronomy: Tough Talk

You wanna know about amateur astronomy? Okay, I'll tell you about amateur astronomy.

First off, there is nothing *amateur* about it if you are enthusiastic and dedicated. Amateurs don't stay that way very long — either they survive and turn into something much greater, or they take up a less demanding hobby, like rubber band collecting.

I have been enthusiastic about and dedicated to amateur astronomy for over two wild and wooly decades. During that time I have experienced first-hand its many delights — watching the moons of gas giants play cosmic peek-a-boo; trying to split close double stars with a primary just .00000083 of an inch too small; taking some of the world's worst photos of the Moon to finally capture thirty-seven crisp shots that won a certificate of merit from NASA; dropping heavy counterweights on my frozen feet; dropping expensive eyepieces in fine Texas soil; forgetting my thermos of coffee — I usually leave it on the kitchen table right next to my flashlight — or worse yet, my film; fighting off mosquitoes as big as buzzards and as loud as freight trains; driving forty-six miles to finish setting up just as a cloud bank rolls in; waiting and biting my nails to the quick until the newest issue of ASTRONOMY survives the mail; convincing myself that there is no way I can afford to buy the 373 new books on astronomy that come out every month; deciding not to begin a life of crime to finance my next telescope purchase; explaining to my wife just why it isn't perverted to sleep with a ten-inch reflector ("It's a Dobsonian! There's no cold metal!"); explaining to my ten-inch reflector why it cannot share our bed; working on my secret multipurpose ray that will rid the world of dust, smog, bad seeing, drive errors, film grain, reciprocity failure, vapor lights, and tube flexure; and trying to explain to people why, in the city, I tend to scream, "Less light!" and in the country, "More light!"

You wanna know about amateur astronomy? Really? I've written articles about it, two of them for this magazine, and now a third. I told you some of the good stuff and only hinted at the other side of the coin. You really should know about it, though. I mean, I'm really obligated to warn you about it, aren't I?



I can hear some of you gasping. Yes, I can sense some feathers ruffling. Several of you fine readers are already baring your fangs. "What?" you say. "This guy's gonna knock amateur astronomy?" Well, don't strike yet. I warn you. I'm as tough as the grinding of a perfect f/4 mirror. I'm experienced. I've paid my dues.

Wanna listen?

Can you take it?

If you suspect that you cannot, I suggest you pass this article up — what follows is not pretty.

To begin, I will shock some of you by writing that amateur astronomy is a tough, tough hobby. Now, I'm not talking about the department-store-17,000-power-imported-refractor taken-out-in-the-backyard-once-a-year amateur astronomy. I'm talking about no-holds-barred-serious stuff; the kind where you really fall head over heels in love with the stars. It's like getting married or adopting a child. Folks, it's a serious business.

Pay attention now.

You've got dedicated, talented people out there who break their backs to make diffraction limited optics and get them to you within a reasonable length of time.

Now, for them, *reasonable* might mean six months. For you, it's six days. And it's tough not to come at them like bats out of you-know-where when they're a few weeks overdue with delivery. Y'know, the shipment of optical glass ended up in Roanoke instead of their factory in Topeka. It's tough not to, but if you're gonna stay sane in this business, you've got to know when to bend.

Good optics are like good stews, they take time to cook. If you rush them, they're just not as tasty. So, the first bit of toughness required of you just might be not being tough in the first place, but patient and understanding. Unless it's a Rolls-Royce, a car is guaranteed for only a few thousand miles. When you get down to it, a telescope is guaranteed for as long as there's something to hold its mirrors in place. That *requires much care* and time.

The second tough requirement is: You must be patient and understanding with your telescope.

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"The telescope?" you say. "He's crazy." Let's face it, though, most beginners expect too much from the poor things. That gets its start in the primordial ooze of department stores and their catalogs, where new recruits are greeted with ads and displays that guarantee their 60mm refractor will reach 1000 power easily. Do you have any idea what this does to a 60mm lens, especially if it's plastic? It makes it nervous. Who can blame it for turning all that light into pudding? And who gets the blame? You guessed it — the telescope.

If we're new at playing the guitar, and we rush out to purchase the finest guitar available, we don't take it home and expect to sound like Chet Atkins, do we? Well, that is precisely what we do all too often with a new telescope. Immediately, its owner expects a symphony of high-resolution to pour through the eyepiece. And if it doesn't seem to happen, then the new recruit will usually get angry and call it horrible names like . . . well, we'll skip those. Some even get violent and slap the tube. Yes, cruelties such as this have been known to happen, horrid as that may seem. Even more horrid is the fact that, without giving the poor thing another chance, they box it back up and sell it for half-price in AstroMart or their own local club newsletter to someone else who might do the same thing, if he's not tough enough with himself.

The third tough requirement is: You must be patient and understanding with yourself. Let's face it, there are going to be some crystal-clear nights when you just won't feel like setting the thing up, much as it wants to be set up. On nights of fine seeing, a nice telescope will cry to you from its storage closet and make you feel guilty for not taking advantage of the night.

More often than not, you will listen for a while, give in, and suddenly disappear from events like your little boy's first speaking part in the school play, or your first family reunion in twenty-six years, or your pastor's first visit since you joined the church thirty-three years ago, or the fifth installment of *Cosmos*. Doing so can do several things, all of them potentially threatening. It can make your wife, if you still have one, begin to have bad thoughts about your telescope (the "woman scorned" sort of thing). It can make those close to you wonder who you are ("Mommy, didn't he used to hang around here a lot?").

Yes, you can easily become an astroholic if you are not tough with yourself. Remember that *moderation* is the word. Too much of a good thing, like too much carrot cake, can turn you against astronomy real fast. You must learn to be firm with your telescope. Firm. Even if it means walking right up to its storage closet (don't open the door!) and shouting "Not tonight! And that's final!" It's a harsh thing to do, I'll grant you, and it will earn you some stares of dismay, especially at family reunions, but it is a helpful, cleansing gesture. And it works. Telescopes respect authority.

The fourth tough requirement is: You have to be patient and understanding with your relatives and friends. Let's face it, if you observe from your backyard, you immediately feel less friendly toward your neighbor, especially if he leaves the backyard light on because his registered collie is afraid of the dark. During those years B.T. (Before Telescope), you didn't even know your neighbor had a backyard light. Now the thing is an obscene intrusion on your right to darkness. And you'll just know he's doing it to aggravate you. That's why it comes on right after you've spent the better part of an hour aligning your scope to the pole star.

Suddenly, you'll want to build a solid cedar fence twenty-seven feet high and find out that will cost as much as a dome, both of which you can't afford. You begin thinking barbaric thoughts. Must you turn into a barbarian to protect your hobby? Of course not!

You're a *civilized* amateur astronomer. So get tough with yourself, not others. Your neighbor just might turn off that light if you ask him kindly. And there are special filters (not really very expensive) which can help you deal with vapor lights. And when all else fails, you can always load up the scope like thousands of other dedicated individuals do and search for dark skies elsewhere. Sure, you have to get a little tough with yourself to go to this trouble, but who ever said amateur astronomy was easy?

And then you have to deal with your relatives. If you're not careful, you're gonna feel the same way about them. You'll get angry with Uncle Jack because he can't see a blamed thing in that 4mm eyepiece. Granny Schmidt is gonna get on your nerves because she doesn't want to go out in "that there cold" to see that red glow that just might be volcanic activity on the floor of the crater Plato. You're gonna bite your tongue when your clumsy cousin stubs his toe on your tripod and knocks your alignment out of whack. And, of course, your allergic father-in-law is bound to sneeze on your best Erfle eyepiece.

You're gonna get disgusted with everybody in the whole world who couldn't give a tad about an occultation, or Jupiter's darkening Red Spot, or the fact that the Moon just came up upside-down. You are going to suddenly realize, and live with the awful revelation, that there are actually human beings, live human beings, out there who do not care. There will be those who criticize you for wasting your money on such things while there are children starving in Zimbabistan.

Little cuts like that will take their toll, and if you're not tough with yourself, you just might start agreeing with everyone. There is no easy way out for this problem. You'll have to suffer the bad and relish the good if you truly want to be an amateur astronomer. Just resolve not to expect so much from others and be content with your love affair as it is: a one-to-one relationship with you and the universe. The rest will work itself out. With time, you will find someone who appreciates astronomy as you do. Who knows? It may turn out to be Uncle Jack!

"Amateur astronomer" is not a degrading term. On the contrary, it is a badge of honor. A badge of merit.

Amateur astronomy does not promise you a rose garden. Usually, it does not promise you fame and fortune. All it promises is a chance to travel from one end of the universe to the other in a single night; a marvelous, magical, sightseeing adventure available to anyone who is not afraid to get tough with himself. The universe does not suffer a sense of obligation to anyone. It is there; it is awesome. It allows itself to be observed and commands appreciation and respect from all who sincerely look upon its wonders. But it does not demand our attention; it does not need our worship.

But, for those who strive to embrace its majesty, it will, with time, grant certain favors. If you are persistent and worthy, there will be times when it will smile down upon you and whisper special secrets which only you will understand.

That's its way of saying, "I appreciate your caring."

That, my friends, is when your toughness gains you star stuff!

You wanna know about amateur astronomy? Then get tough!

Ken Fulton
Temple, Texas

Ken Fulton's previous articles are "What Accessories Do You Really Need?", April 1980; and "Read 'Em and Don't Weep," July 1979.

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An Interview With Dr. Fred Scarf

Dr. Fred Scarf is a senior scientist for TRW Space and Technology Group in Redondo Beach, California. He is the principal investigator behind the Voyager spacecraft plasma wave experiments. Through Voyager, Pioneer and other missions, Dr. Scarf has brought the sounds of the solar system to the ears of Earth.

ASTRO: Dr. Scarf, you're a physicist in the area of particles and fields . . .

FS: Yes, I was trained so. Although I was involved in high energy physics and fundamental particles early in my career, I've been working in space plasmas for 20 years.

ASTRO: To non-scientists, plasmas are often mysterious. When I talk to the people who aren't involved with Voyager about particles and fields experiments, or about your recordings of plasma wave "sounds" around Jupiter and Saturn, they say, "It's wonderful, but what does it mean?"

FS: Well, there's certainly the fun of exploring these exotic objects. But I think it means a lot in terms of understanding ultimately how our own system works. We can't do certain experiments here on the Earth so we make observations, try to generalize what we have, and write down laws. We think we've understood things, but controversies develop and we can't control things.

ASTRO: Could you give an example?

FS: Sure. In the space around the Earth there are plasma wave phenomena which kick particles back down into the atmosphere. Some people have begun to wonder if these waves might actually come from electrical power lines, our man-made power grids, and other places. But how can we tell? We can't do the experiment by shutting off all electric power. So the studies involve looking at the difference between Saturday and Sunday and the weekdays. However, when we go to Jupiter and find these same waves, we're convinced that they didn't come from any power grids. That's just one small example, a tiny example, of what we've learned by going to another planet.

ASTRO: The Voyager plasma wave experiments were probably the most mysterious of that mission to the "man in the street" who heard your recordings on the evening news. First of all, what is a plasma wave?

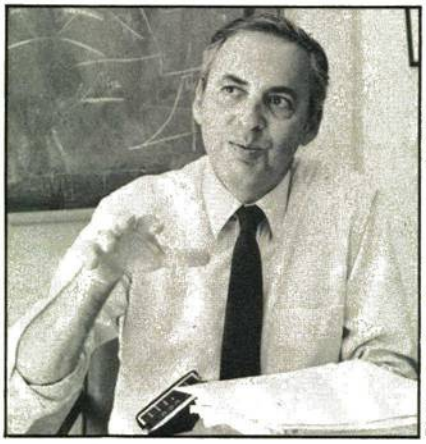
FS: It's really very simple. There are two kinds of waves. One kind is a low frequency radio wave similar to the waves that we use to communicate with submarines — longer electromagnetic wavelengths. We use them because they go through water. They're not very exotic, but we just don't think of radio waves in the audio frequency range.

ASTRO: Normal AM broadcast waves are about a million cycles per second, aren't they?

FS: Yes. But these radio waves have frequencies of a few tens to a few thousands of cycles per second.

ASTRO: I see . . .

FS: The other kinds of waves are more like ordinary sound waves. Basically, they are pressure variations in the hot gas around the planets, variations so minute that we wouldn't pick them up with our ears or with an ordinary microphone. But in the gas that's up there, called a plasma, the atoms are broken apart. When the pressure variations occur in that case, they're electrical oscillations. We pick them up on Voyager with what I call an "electric microphone." If you took a car radio antenna and just plugged it into the microphone jack of your tape recorder, you would pick up only these plasma waves. So the sound waves and low frequency radio waves together make up the plasma waves.



Photos by Ken Montegomery of TRW.

ASTRO: What makes an ordinary gas into a plasma? What breaks up the atoms?

FS: Temperature. Once you leave the Earth's surface and go out about 80 or 90 miles, it is hot enough that all the atoms are broken apart. One or more electrons come off. So the electrons float around freely. So do the atoms — minus a few electrons — so they are also charged. That's all a plasma is, just hot gas in which all the atoms have a charge.

ASTRO: How do you turn pressure waves in a soup of charged atoms into the music that we hear on your tapes?

FS: Some of the stuff we don't do anything to. With our "waveform" data, it's very much as if you took a pair of earphones and actually touched the two antennae on Voyager and listened. Voyager digitizes the "sound" and radios it back to Earth. We simply convert it back and listen to the sounds as if we were sitting on Voyager.

ASTRO: Doesn't that take a lot of data transmitting capability?

FS: Yes. We never do it for very long — just 48 seconds. We took 16 of them in the two days around closest approach to Saturn. The data comes back as a picture frame, but it doesn't look like much. The other things that we do, the other way we listen to the plasma sound, are — well — they involve more action on our part here on the ground. We have sixteen audio filters on Voyager. Each one of these filters only lets a certain pitch through. Then we can measure how much energy there is at that particular frequency. We sample the strength every four seconds and store it in the spacecraft.

ASTRO: And that runs all the time?

FS: Right through the flyby.

ASTRO: How do you get the sound back here?

FS: It's radioed back as digital data. Then we reconstruct the sound with a music synthesizer. Say that we know one channel was measuring at a thousand cycles per second. We turn on a sound generator here in our lab on Earth at 1000 cycles per second and make it go up and down in intensity just the way Voyager measured it. It sounds much more musical than the original stuff, in fact, it sounds maybe a little too musical to be faithful to the original.

ASTRO: It sounds like a science-fiction movie soundtrack.

FS: But it's really Saturn's plasma waves — accurate to the extent that we can make it in this reconstruction. It's really sort-of smoothed out because we're not measuring many frequencies with these filters — though we could, if we had our whole waveform channel working. And we measure them intermittently — just every four seconds. Then we tend to smooth the whole thing out and reconstruct it. But otherwise it really is a representation of what we measured up there.

ASTRO: The outer planets aren't the only ones that have been explored through the medium of sound. The Pioneer Venus Orbiter also had a plasma wave instrument

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FS: Yes, but it was a very limited instrument on Pioneer Venus, and there are only four audio filters, and we don't have the waveform channel. On Voyager we have the waveform and we have 16 filters, so the sounds that we can reconstruct at Venus are simpler, with fewer possibilities for complications.

The physics is also simpler at Venus. The planet doesn't have its own magnetic field, and there is less interaction with the solar wind than we find at Jupiter and Saturn where fields are enormously complicated. It will take us years to straighten it out.

ASTRO: So in that regard the Earth is more similar to Jupiter and Saturn than it is to Venus.

FS: That's right. The Venus/solar wind interaction is different. It's much more like what we would expect to find at a comet, which would also have no magnetic field.

ASTRO: I read recently of evidence for volcanic activity on Venus. Did this come from that experiment?

FS: We put data for that together from three instruments on Pioneer Venus almost accidentally. When we look at the plasma wave data on the night side of Venus where the spacecraft is quiet — when the solar panels are in darkness and we're running on battery power — we don't have some of the electrical noises that develop on the spacecraft. Anyhow, we detected impulsive signals that we assumed could be interpreted as lightning — low frequency radio waves. For several years we'd been trying to make a map which will find out if these signals are clustered in any particular place on the planet. We found two regions on the planet that appear to be the source of the electrical signals. Both of them, according to the radar map, are mountainous regions.

When I got to the Venus conference, I learned that Hal Masursky had been looking at the terrain features and had identified these two regions as volcanic on the basis of, well, I can't really give a detailed explanation. It has something to do with the slopes and the ways in which he could see different terrains. Also, Roger Phillips had been studying the gravity field around Venus and he found that there were gravity anomalies in these two places that suggested they were very young.

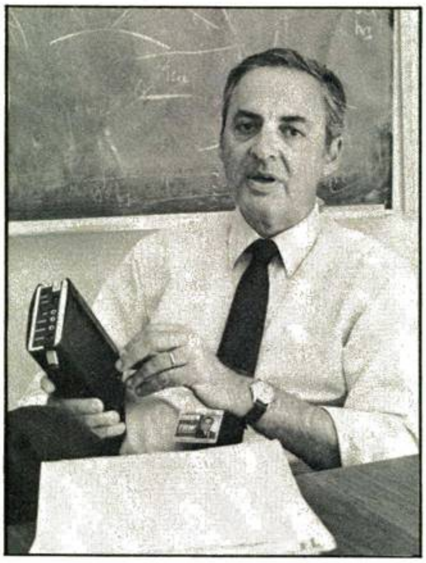
Finally, the radar people had other evidence that the material in these two places was different. When data from these instruments appeared together, they indicated not just volcanos, but possibly active volcanos that may have created the lightning we detected with their plumes.

ASTRO: Do we ever see lightning around terrestrial volcanos?

FS: It's very common on Earth. This won't go on your tape recorder, but I can show you a picture of Vesuvius with lightning coming from it. It's somewhere in this pile here. . . when you see these pictures you'll know that it's not a fluke. I have two of them, one is Vesuvius and one is that volcano in Iceland, Circe, I think it's called. And the reasons that we think this is real at Venus, well, there are some additional reasons. The Soviets landed near one of these regions, the Beta region — ah, here's Vesuvius, and here is the volcano in Iceland.

ASTRO: Incredible!

FS: Well, the Soviets had a different kind of instrument to detect lightning. It landed near one of these regions and they detected up to 70 flashes per second. It has always seemed unlikely to me that there is that much lightning in the clouds normally, whereas if you were to look at something like an active volcano, it's quite common to see that many flashes. So it's an intriguing concept, and it's one that planetologists are starting to take very seriously.



ASTRO: What causes the lightning in volcanos?

FS: As the material comes out, charges are transferred from friction, that's all. The interesting thing to look at in the next few months will be the data recovered by the Russian landing in March. They landed very near one of these two regions, Beta Regio, and again they used lightning detectors. We'll look forward to that data.

ASTRO: Are experiments like this recording similar plasma wave "sounds" from space near Earth?

FS: Many instruments here at Earth are making related plasma wave measurements. With broadband instruments we've detected all the things at Earth that we detected at Jupiter: lightning whistlers, the chorus, the sound at the bowshock and so on. But it's easier to hear the Jupiter sounds because the frequencies are lower there than they are at Earth. High frequencies are much harder to hear. The electrons that "chirp" upstream from Jupiter make sounds at three kilocycles — we can all hear that. On Earth it's 20 to 30 kilocycles.

ASTRO: Those are frequencies only young children and dogs can hear directly . . .

FS: We can scale them down in frequency, but as you go outward in the solar system, the plasma sound frequencies naturally fall down into the audio range. It was very pleasant to find this out, and be able to talk to the press about it. We're not used to doing it on Earth because of the higher frequencies.

ASTRO: Why are they higher?

FS: The density of the solar wind is greater as you get closer to the Sun, and the frequency depends on its density. As you go in to Venus, it's even higher than it is at Earth. Actually, as we got to Saturn, we found some of the frequencies so low that they drop off below the audio range. I think Jupiter was the highlight in terms of falling right into the audio range.

ASTRO: What do the sounds we're getting from around Earth tell us?

FS: One of the many questions that comes up has to do with the structure of the chorus. Why does it produce a chirping sound? Why do lightning whistlers sometimes trigger other strange emissions? One thing it means is that somewhere out there in the Earth's magnetosphere energy is available. We can tap that energy with the waves. But in just listening to the natural signals, we haven't gotten very far. So now we're starting controlled experiments. In Antarctica we actually experiment with the plasma waves using a long transmitting antenna. On a future shuttle flight, a package designed by my colleagues here at TRW, Bill Taylor and Bob Fredericks, will be carrying that kind of active experiment up into orbit with a very high-powered transmitter. The name of the project is WISP, Waves In Space Plasmas, and they are going to try to be doing these controlled experiments in space to find out where the energy is stored and how to tap it for scientific and practical

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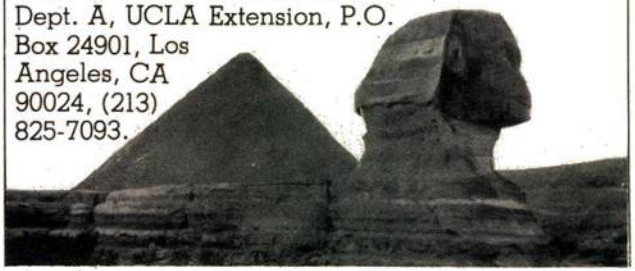

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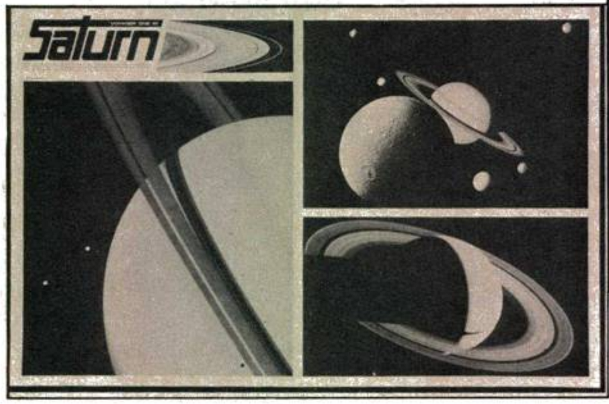

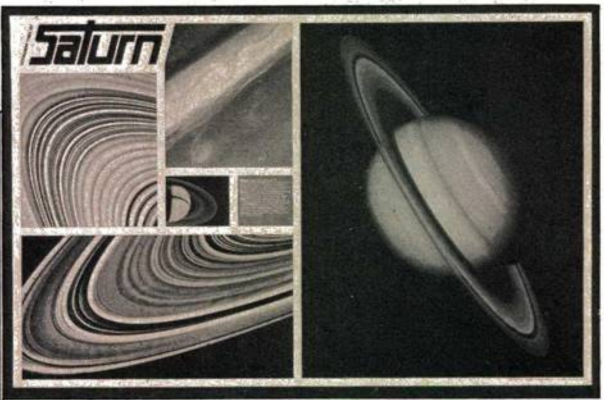

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reasons.

ASTRO: Is that a possible future energy source for us?

FS: Not energy in the sense of running your car, but energy in the sense of being able to control phenomena in the atmosphere, including auroral emissions and some other things that are just being explored.

ASTRO: Climate and weather control?

FS: Well, there are some people who think that these phenomena have a very direct bearing on climate and weather. There are others who completely dismiss it.

ASTRO: Where's the mechanism? How could it happen?

FS: One way to make it happen, or to see if something really does happen, is to actually make a perturbation. You might actually start dumping particles from the Van Allen belts into the atmosphere — then see if it changes anything.

ASTRO: What about the planetary magnetotails? Doesn't an energy build-up occur in the tails, I believe they're called substorms, and the energy then returns to the planet?

FS: Right — and this is a very important but poorly understood area. When the Sun pumps energy into the Earth's magnetosphere, it doesn't all come right in the way it sometimes does over the poles. Then you get aurorae. Sometimes a lot of energy gets stored for a few days before something triggers it. Then it comes rushing back and causes a storm on the ground. This whole sequence is called a substorm even though it's more important than the ordinary storm.

The storage is somewhere back in the Earth's tail, but the Earth's tail has never been explored in any organized way. Pioneer 7 or Pioneer 8 flew by on its way out to the interplanetary medium, at 500 or 1000 Earth radii, and found all kinds of chopped up magnetic structures back there. There was an attempt to anchor a spacecraft around the Moon on Explorer 33 but that didn't work, though the craft did investigate some of the region. So we really don't have an understanding of what goes on there.

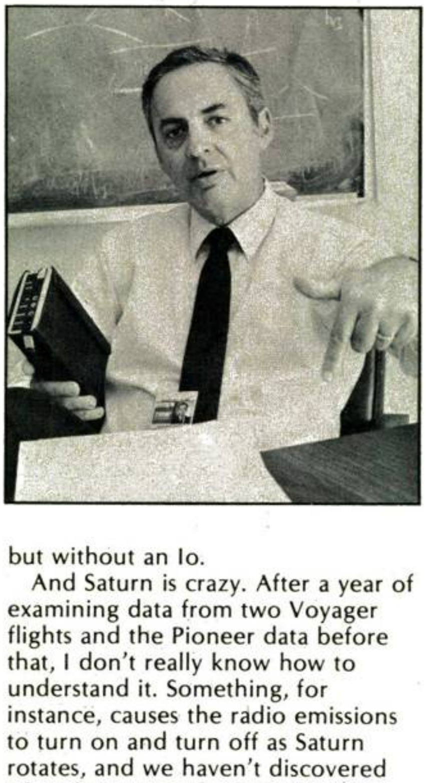
ASTRO: Do substorms have definite effects on Earth itself?

FS: Oh yes. They dump energy into the upper atmosphere. This changes the magnetic field and makes all kinds of perturbations, not only in the field, but also on the surface of the Earth. These substorms affect radio wave transmissions and power lines, so they are quite noticeable on the Earth. They're important commercially, especially in communications and power distribution. They're important to the military, too, because you must know when the Earth is going to get murky and disturbed, and when communications will be lost.

ASTRO: What about similarities and differences in the planetary magnetic fields of Jupiter, Saturn and Earth?

FS: Oh, they're crazy, just crazy. In a way, Jupiter is simpler because it's so different, dominated by its moon Io. Io's volcanos erupt gas, and that gets converted into plasma. Lots of plasma. From an astronomical point of view, Jupiter and Io are a binary; Io has a strong influence in the magneto-world.

Jupiter without Io would be extremely different. The composition of the plasma, its density, everything is contaminated by Io and its volcanic emissions. The Earth, of course, is a sort of a small Jupiter — but without an Io.



And Saturn is crazy. After a year of examining data from two Voyager flights and the Pioneer data before that, I don't really know how to understand it. Something, for instance, causes the radio emissions to turn on and turn off as Saturn rotates, and we haven't discovered what that is. We don't find that it turns on and off because it's like a searchlight going around — it's more like somebody turning a light switch on and off.

ASTRO: You mean it's operating like a big radio transmitter — but variable?

FS: So are Earth, Jupiter, the Sun and Saturn; they're all radio emitters at very high frequencies. But I think we understand the situation in the other cases. At Jupiter we can watch the signals being beamed around as the planet rotates, and we understand why — the magnetic field is tilted and it's offset. But at Saturn the field isn't tilted and it's not offset. We don't know what the asymmetry is.

There also seems to be a very big difference between the northern and southern hemispheres of Saturn, and we don't understand that either. We hoped we were going to understand all this when Voyager 2 went by, but I wouldn't say that we got enough to figure out these things.

ASTRO: Will future exploration shed light on it?

FS: There is no plan for any future exploration. We've accumulated all the data we're going to get. The big problem you have when you do this kind of exploration is that you run into theories and concepts that are based on the idea that whatever you are seeing has been there forever.

We assume the atmosphere of Venus is static, and that it's all from outgassing, not volcanos. The rings of Saturn are the way they're been for millions of years, not that stuff is falling in now. And, of course, none of that is true.

Io's volcanos were not supposed to exist either, but once you see something like that, it gives you the strength to think of everything changing as you watch it. Then you look at the atmosphere of Mars: where is it? Where's the water? It's an important question — maybe the Russians will answer it. Did you read *Science* or *Aviation Week* this week? They're talking about the end of the planetary program.

ASTRO: Are the Soviets doing intense planetary exploration?

FS: They just landed two spacecraft on Venus, and they are planning at least one more mission to Halley which will stop by Venus on the way. And there are rumors of other missions including one to Mars. The Europeans, ESA people, are planning a Mars mission called Kepler; the Japanese are doing comet missions. We've given up and the others are going on.

ASTRO: How well are we in contact with the Soviet planetary scientists?

FS: It's a strange contact. I'm a member of a group that's supposed to meet regularly, but I don't think we've ever met. We do correspond — and I think I'm going over there this spring. I'll try to take some Pioneer Venus stuff.

ASTRO: Well, good luck. Maybe you'll initiate a mutual exchange. Finally, after all this, is there truly a "Music of the Spheres?"

FS: (referring to a recording recently made at TRW) Only what we've put on record here at the lab.

Myra Weir
Big Bear, California

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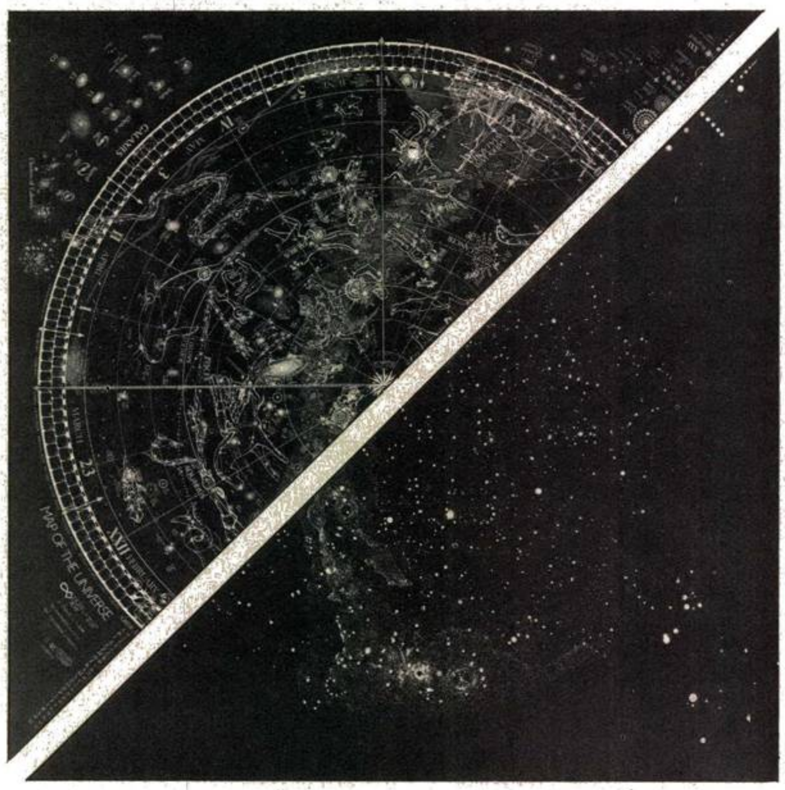

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eye on the sky

cluster of planets prominent

by Fred Schaaf

the wanderers

As the nights grow warmer, the skies are replete with planets from sunset to dawn. The four bright planets are still in good viewing position and the other two naked-eye members of our solar system are at their peak for the year.

The three central planets in May skies are Mars, Saturn, and Jupiter. As the month opens, these worlds lie along the extended length of Virgo, shining brightly at her head, heart, and foot.

At the head of the Virgin, **Mars** lingers, making a leisurely loop to resume direct (eastward) motion on the 13th. For the whole month the Red Planet remains the most distinctive object in the heavens — a negative magnitude point of ruddy light near the celestial equator. Mars fades from -0.8 to -0.1 magnitude during May; you can check this by comparing it with the -0.1 magnitude Arcturus, high above Mars, around Memorial Day.

While Mars turns to the east, **Jupiter** and **Saturn** continue to retrograde west. Since Jupiter is faster than Saturn, the distance between these three planets decreases noticeably.

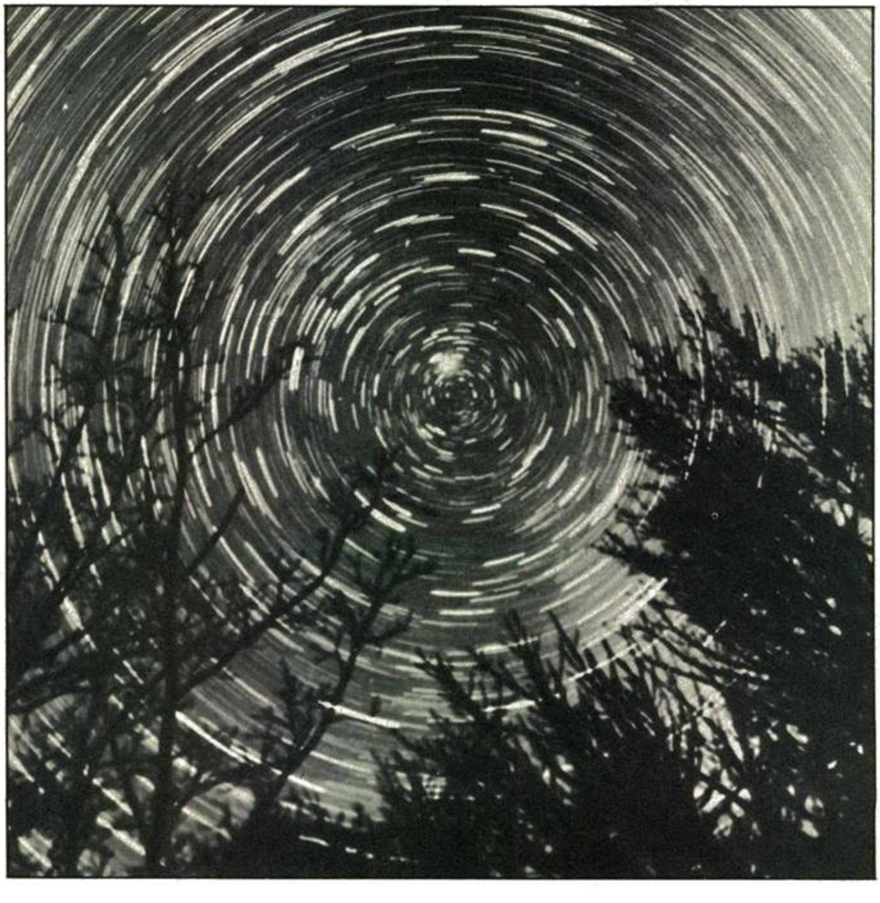
At mid-month, while Mars is still well to the west, Jupiter and Saturn form a pattern with first magnitude Spica; both of the giant planets are roughly 10° from Spica, with Jupiter pursuing and Saturn leading on their nightly journey.

Saturn appears distinctly brighter than Spica, although it fades from 0.6 to 0.8 magnitude. Jupiter, just five days past opposition on May Day, also fades a little, but shines around -2.0, and is the chief luminary in the heavens when the Moon is down. The Moon passes north of Mars, Saturn and Jupiter from the 3rd to the 6th, though all are north of the ecliptic.

As morning twilight begins, and Mars, Saturn and Jupiter set, the radiant lamp of the Morning Star appears in the east, it almost seems that **Venus** is in "opposition" to each of these planets in turn this month. Although our "sister planet" is just a month past greatest elongation, it is already rising after morning twilight begins. But 1982 will not be a very good year for Venus observation in the northern hemisphere because the planet loses a third of a magnitude this month and will continue to fade until next year.

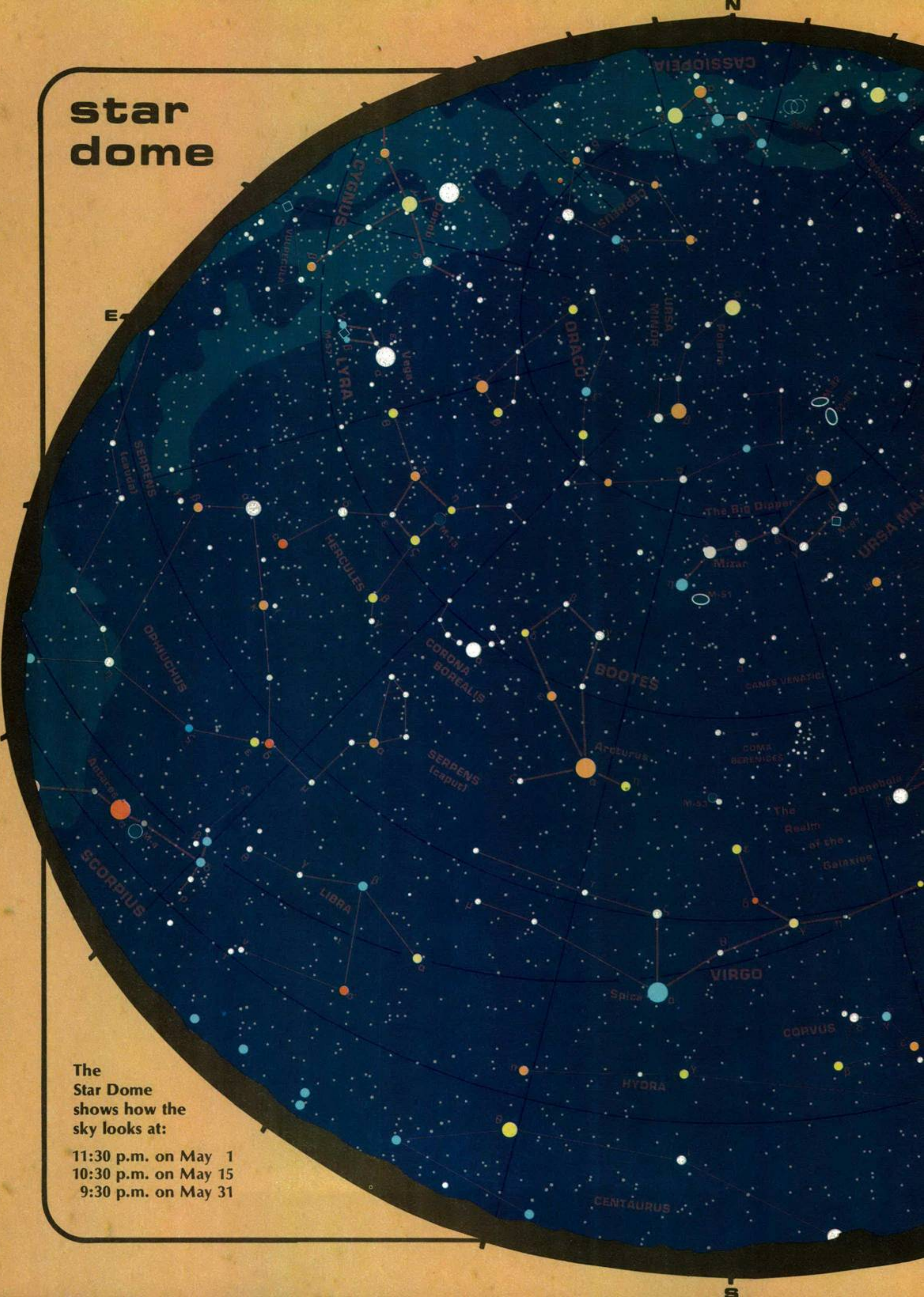
May is also a good month for glimpsing some of the least observed naked-eye planets. On the evening of the 8th, **Mercury** is at greatest elongation, 21⅓° from the Sun. The separation is far less than maximum, but this will be the best apparition of Mercury in 1982 for North America.

For the first 10 days of May, Mercury sets after the end of astronomical twilight (when the Sun is 18° below the horizon), and fades from 0.0 to 1.0 in



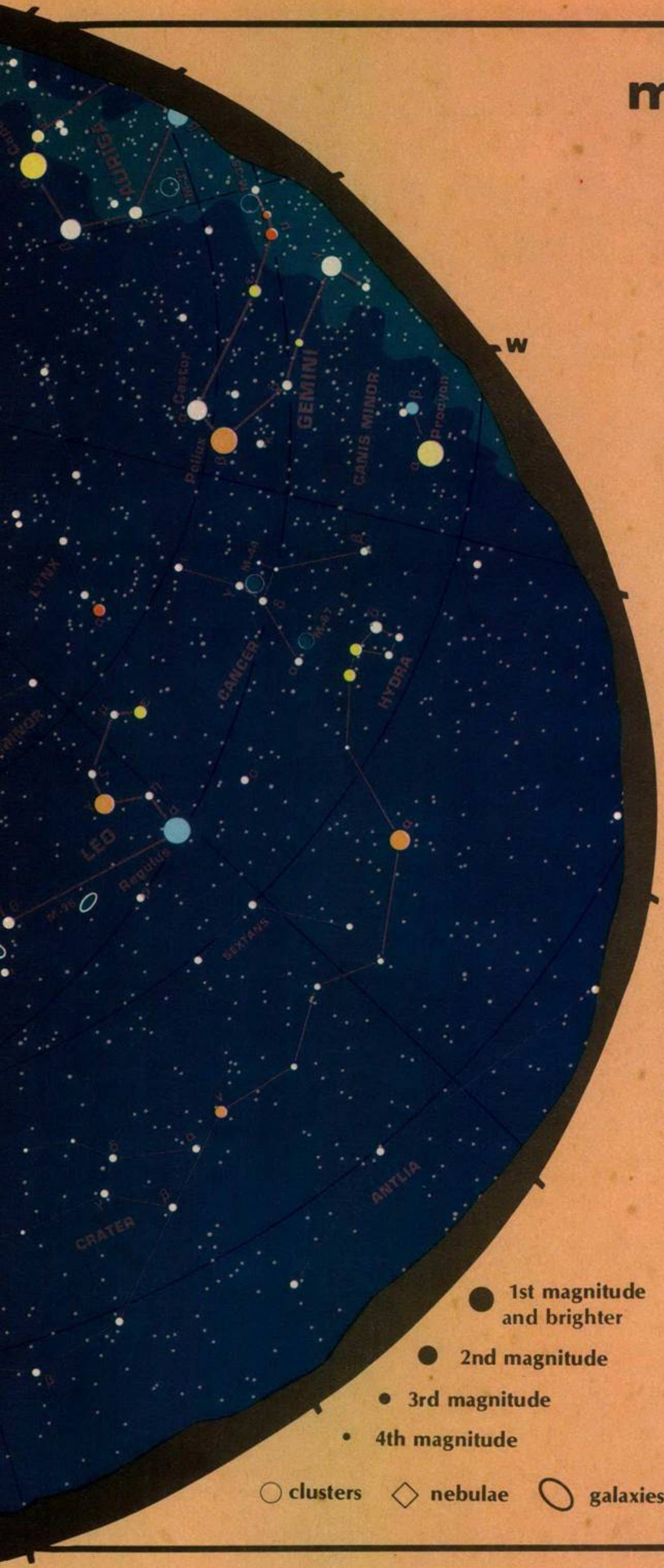
Dave Abbott took this sunset photo of the crescent Moon and Venus from Victor, Colorado. He used a 135mm f/2.8 lens and recorded this image with a 4-second *exposure* at f/5.6. At left is a 1-hour exposure of circumpolar star trails made by Steven Simmerman with a 50mm f/1.4 lens and 2415 film.

star dome


N
E
S
CASSIOPEIA
CEPHEUS
CYGNUS
Deneb
VULPECULA
LYRA
Vega
M-57
DRACO
URSA MINOR
Polaris
HERCULES
M-13
SERPENS (cauda)
OPHIUCHUS
CORONA BOREALIS
BOOTES
The Big Dipper
Mizar
M-51
M-97
URSA MA
CANES VENATICI
COMA BERENICES
Arcturus
SERPENS (caput)
M-53
The Realm of the Galaxies
Denebola
Antares
M-4
SCORPIUS
LIBRA
VIRGO
Spica
CORVUS
HYDRA
CENTAURUS

The Star Dome shows how the sky looks at:

11:30 p.m. on May 1
10:30 p.m. on May 15
9:30 p.m. on May 31


AURIGA
GEMINI
Castor
Pollux
CANIS MINOR
Procyon
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LYNX
M-44
M-67
CANCER
HYDRA
MINOR
LEO
Regulus
SEXTANS
ANTLIA
CRATER
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

may sky almanac

3rd	Eta Aquarid meteors are at peak activity today, but the Moon won't set until just before morning twilight starts. Expect to see about 10 to 20 meteors per hour coming from the region of Aquarius in the predawn hours.
7th	The Moon is Full at 8:45 p.m. EDT.
8th	Mercury is at greatest eastern elongation tonight. Look for it low in the west-northwest in the hour after sunset. This is the year's best opportunity to see Mercury for northern hemisphere observers.
11th	The Moon is at apogee (farthest from Earth) this morning: 251,925 miles.
15th	By midnight in the middle of May, you can see the stars of summer well above the horizon in the east; late winter's stars and those of spring have either set or are sinking in the west.
16th	Last Quarter Moon is at 1:11 a.m. EDT.
19th	Venus is at aphelion (farthest from Sun).
23rd	The Moon is New at 12:40 a.m. EDT; it will be at perigee (closest to Earth) late tonight: 222,952 miles. Also, Uranus will be at opposition to the Sun.
29th	First Quarter Moon is at 4:07 p.m. EDT.

Observing from Aiea, Hawaii, might be a vacation pastime for some, but not for Ray Fabre' — he lives there. He took this shot of the southern end of Scorpius using an 8-inch RFT and a 50mm f/1.4 lens on piggyback. Messier objects in this dense Milky Way region are easy to pick out in this 5-minute exposure.

magnitude. By a fortunate coincidence, a number of good comparison stars — Capella 0.1, Betelgeuse 0.7, and Aldebaran 0.9 — will aid your observations. Mercury is 8° north of Aldebaran on the 10th and 11th. Late next month, these two will have an observable and unusually close conjunction in the morning sky.

You'll need dark skies to see distant **Uranus** with the naked eye when it comes to opposition on the evening of the 23rd. The Moon will not interfere because it will be a slender crescent less than one day past new, low in the west after sunset.

Is Uranus really visible to the naked eye? At magnitude 5.8, it certainly is. Use binoculars to help you in this exacting task, and try to find comparison stars so you can estimate its brightness.

You will need some optical aid to see the passage of Uranus between the stars Omega^1 (magnitude 4.1) and Omega^2 (magnitude 4.6) at the end of May. Uranus is only 7′ north of the latter on April 30 and 4′ south of the former on May 4. The dim planet makes this passage through the gap three times during 1982, but this is the most favorable. The last occurs in November just a few weeks before these objects are in conjunction with the Sun. The proximity of the Sun in late November will ruin an otherwise astonishing sight — the planet Venus racing to pass between the same two stars just 1½′ north of Uranus!

the starry sky

Let's take a look at a swath of sky centered on the meridian — the north-south line running through the zenith. This year, one sector is heavily planet-populated, but the stellar objects there also deserve our attention.

When we look to the north, we see the year's best evening view of the Dippers. The **Big Dipper** part of Ursa Major, the Great Bear, now pours its cosmic contents down into the bowl of the **Little Dipper**. The latter is officially Ursa Minor, the Lesser Bear, home of **Polaris**.

In the Little Dipper's handle only Polaris is bright, but on May evenings the Big Dipper handle high above it is composed of 2nd magnitude stars. The middle star, **Mizar**, is famous for its companion which many people can spot with their naked eye. The companion, **Alcor**, which shines at 4.0 magnitude, lies a full 11.8′ from Mizar.

Follow the handle of the Big Dipper to the spring sky's brightest star, **Arcturus**. This unusual sun is the chief luminary of Bootes the Herdsman. The Herdsman protects his flock from the fierce Great Bear — the name Arcturus actually means "bear-guard."

The small but interesting constellation Canes Venatici depicts the hunting dogs of Bootes snapping at the ponderous bear's heels. Located northwest of Arcturus under the handle of the Big Dipper, they pass directly overhead for many North American observers. The two brightest stars of the constellation are the 3rd magnitude **Cor Caroli** ("the heart of Charles") and **Chara**. Within the bounds of Canes Venatici, not far south of the Big Dipper's handle, is **M-51**, the famous **Whirlpool Galaxy**. You can sometimes see this swirling mass with 7x50 binoculars and a dark sky.

Traveling south from the zenith, we find ourselves amidst the crowds of galaxies that glow in a telescope's field of view like early summer fireflies. Although we cannot see the clusters of galaxies with the naked eye, we can

observe the fine open star cluster of **Coma Berenices**. This irregular scattering of stars is best seen in dark skies.

Before the time of the historical Queen Berenice, the **Coma Cluster** was considered the tuft on the tail of the mightly beast now descending just to the west of our meridian-centered slice of sky. He is **Leo**, whose foreparts form the prominent Sickle that contains first magnitude **Regulus** — "the little king." Regulus is the star closest to the ecliptic; the bright point that marks the other end of Leo is **Denebola** — a beautiful, gleaming double.

Across the south and southeast sky at this hour — from Denebola to the low Libra — lies **Virgo**. In autumn the Sun requires a month and an half to traverse the length of this constellation. It is mostly a faint pattern, but it does possess one very bright star, **Spica**.

Spica is the southern member of an enormous and now seemingly little-known asterism called the Diamond of Virgo — formed by Arcturus, Spica, Denebola and Cor Caroli. It is a useful pattern for locating faint but interesting objects that lie within its lines including the globular cluster, **M-3**, that lies on the line between Arcturus and Cor Caroli. This spring the Diamond contains several interesting visitors. The minor planet **Pallas** is a binocular object near the center of the Diamond, and **Pluto**, a telescopic object, is located two-thirds of the way from Spica to Arcturus.

Southwest of Spica is the prominent figure of **Corvus** the crow, often associated in legend with the much fainter neighbor, **Crater** the cup.

Finally we reach the very southern end of this swath of the May sky. Tucked beneath Corvus and curling slightly up to pass below Spica is the tail of **Hydra** the sea serpent. Still farther south is part of **Centaurus** the centaur — the constellation that contains the heavens' most glorious globular cluster, 3rd magnitude **Omega Centauri**. Sadly, this cluster is too far south to be visible from most of North America. But at least we have the fine M-13 ascending in the northeast in **Hercules**.

skylore

Perhaps the most intriguing theme in the lore of **Polaris** is the association of the star with a mythical super-mountain of the far North. The tradition of this mountain is connected with the north celestial pole, because people noted this was the "still-point" of the turning heavens.

For example, the ancient Sumerians believed "the mountain of the world" in the remote northeast was the abode of the gods. R. H. Allen says that Von Herder wrote of "Albordy, the dazzling mountain in which was held the assembly of the gods." The Norsemen had their Himinbiorg, or hill of heaven — where dwelled Heimdall, who guarded the bridge Bifrost (the Rainbow) that curved from Asgard to Midgard.

The most magnificent of these world-mountains was surely Mount Meru of Hindu mythology. In the legends of the Lamas of Tibet, Meru is "the universal hub, the support of all the worlds," according to Edna Kenton. She says it is also called the "Garden of the Tree of Life" because "the Jambu or Rose Apple World Tree springs from it."

In her work, *The Book of Earths*, Kenton discusses the universe of the Lamas as it is described by L. Austine Waddell. According to her, the Lamas say that our world is just one of many which "all together form a universe or Chiliocosm of which again there are many." This interesting word "chiliocosm" is not to be found in the *Oxford Fnglish Dictionary*, but the meaning is clear from the prefix — chili, which means "thousand." In Kenton's words: "Each universe is set like a jewel in illimitable space, upon a warp or woof of 'blue air' or wind. Crossed thunderbolts are the symbols of this 'blue air,' which is hard and indestructible like a diamond. Upon this 'warp' or 'woof' is set 'the body of the waters,' and upon this is a foundation of pure gold, on which is set the Earth."

Mount Meru is said to spring up directly from the Earth's axis and it is not surprising that the residents of the Himalayas claimed a very great height for it — 84,000 miles!

The Italians of the Renaissance spoke of both Ursa Minor and Polaris Tramontana — above or beyond the mountain. This may be a reference to the Alps or to another mythical mountain, Mons Coelius — Heavenly Mountain. Allen says that even into modern times a popular saying in some languages is "losing his Tramontane" — his Polaris, therefore his bearings in life.

Two renowned Italians of the Renaissance had their own ideas about world-mountains not associated with Polaris or the north pole. One was Dante, whose mountain of Purgatory was located antipodally from Jerusalem. But this mountain was meant to embody spiritual or geographical truth.

The other Italian, Christopher Columbus, certainly believed in the literal truth of his very strange world-mountain idea. Columbus wrote in a letter to Ferdinand and Isabella that the Earth "is not round . . . but of the form of a pear, which is very round except where the stalk grows, at which point it is most prominent." Columbus thought that the immensely raised portion was in Paria, near where he sailed — apparently in northwest South America. In that region — on the tops of three hills which his watchman had seen from afar — Columbus believed there existed the Earthly Paradise.

The Finns too have their north polar mountain. They know Polaris as Taehti, "the star at the top of the heavenly mountain." In another Finnish legend the north celestial pole is Boahje-Naste, "the nail which holds the heavens up, and beside which sits a beautiful maiden who weaves the universe." According to this tale, the world will end when Arcturus the archer shoots down Boahje-Naste, causing the heavens to fall.

ASTRONOMY
IN FOCUS

The Beauty of a Telescope

Sir / Have you ever sat down and thought how important and beautiful your telescope really is? Be it big or small, commercial or homebuilt, refractor or reflector, have you considered how it permits you to see things hidden from most people of this planet, how unique you and your optic friend are, and how wonderful it is to see you two alone in a field at night away from civilization, trying to collect a few pilgriming photons from faraway worlds?

And did you ever notice how quiet your friend is? Unlike electric trains, musical instruments or radio-controlled airplanes, your magical tube doesn't make a sound. And best of all, it doesn't use any energy.

All you have to do to enjoy astronomy is let those fabulous optical pieces concentrate age-old light particles and form an awesomely beautiful sight for you to feast upon.

Aren't we lucky to have these great instruments? How beautiful and graceful they are. I love them.

Andre Germain
Westmount, Quebec

Planets & Poetry

Sir / Your comments in the "Skylore" section of Eye on the Sky (ASTRONOMY, December 1981) about allusions to Venus in 19th and 20th century poetry bring to mind something I noticed in another poem: "On First Looking into Chapman's Homer " by John Keats. What caught my eye as an amateur astronomer were these lines:

"Then felt I like some watcher of the skies / When a new planet swims into his ken. . ."

Since Keats lived from 1795 to 1821, and Uranus was discovered in 1781, these lines may have been inspired by his fellow-Englishman Herschel's discovery of Uranus. Piazzi's discovery of Ceres, which occurred during Keats's lifetime, is another possibility, but personally I would think that the accomplishment of a fellow-Englishman — already noted in the textbooks used by Keats as a schoolboy — would loom larger in his mind than a non-countryman's discovery of a much smaller object.

This possible reference to Uranus in poetry is the only one I know of. Do your readers know of others?

Robert A. Purvis
Anchorage, AK

Time's Machine

Sirs / My new telescope wasn't large, just an awkward three-inch reflector mounted atop three trembling black iron legs. But that black cardboard tube seemed to promise the power of Palomar.

The first stars of that soft long-ago summer evening began to appear — fireflies igniting beneath black shadows at the edge of the woods.

Above the trees, transparent summer dusk deepened from aqua and cerulean to a deep cobalt blue. The first quarter Moon, a thin silver crescent, hung above the western horizon and near it, a star.

That "star," a soft smear of light, at last trembled into the telescope's field of view.

That golden glowing disk was haloed with rings! Saturn! A miracle come to focus within that tiny lens. The very stuff of dreams and fantasy.

The year was 1953 and I was a star-smitten fourteen-year-old. *Collier's* magazine was publishing its great series on the Conquest of Space while rockets stitched vapor-trail filigree above White Sands, New Mexico. UFOs crisscrossed the celluloid skies of Hollywood and, seemingly, the skies above every town in America.

Great stacks of science-fiction comics nested next to my bed. "Weird Science" and "Weird Fantasy," laminating with books on science and astronomy — Werner von Braun, Wally Wood, Ray Bradbury, Chesley Bonestell, Robert Heinlein and Arthur C. Clarke. All these heaps of fact and fancy beckoned from a world I desperately wanted to see.

Now, Voyager 1 has photographed and transmitted images of Saturn with all its grand passacaglia of rings and moons. Within the safety of our living room trajectories, we saw those live color images etched across a billion miles of space, synthesizing themselves before our eyes, an everyday miracle.

This is the day of science fiction, but its annunciation arrives in stacatto, its harmonies blurred in the counterpoint of election reports and baseball scores.

Sandwiched in calendar clutter, *we* are the time machines, one foot mired in industrial waste, the other leaving tread marks in Moon dust.

Bruce Bond
Milwaukee, WI

Painting the Night Sky (Accurately)

Sir / Painting the night sky on your ceiling (ASTRONOMY, December 1981) is a delightful idea for masochists or those who aspire to sainthood through self-inflicted punishment. Even after laboriously mapping the constellations and the bright stars with carefully plotted accuracy, how can the night sky aficionado live with the awful truth of randomly dotted stars? Who could fall asleep under such a canopy of falsehood?

At any rate, for those who can find no more certain way to insanity than this, the following idea will simplify and greatly improve the accuracy of the project.

Borrow an overhead projector from an audio-visual department of a large corporation, university or library. Then find star charts that are 8"x10" or smaller — photographic negatives of the night sky will also work. Make flat copies of these on a good copier and prevail upon someone to make acetates or transparencies of your flat copies. Now use the projector in your garage to make a template on a large sheet of suitable material, or project the image directly onto your ceiling.

If the copies that you used are good, and you've taken the time to follow them carefully, your star-studded ceiling should be accurate right down to the last tiny dot.

Sandy Hartman
Jacksonville, FL

Editor's note: There are many ways to paint the night sky on your ceiling. We chose a simple method that required a minimum of equipment.

Of Titan and Titans

Sir / Could you please answer the following questions about Titan:

What is the inclination of its axis?

What symbol does it have?

Who were the Titans of Greek mythology?

Robert Boyd
National Park, NJ

— Since no one has yet been able to measure a rotation period for Titan (all we can see are its featureless cloud-tops), we don't know what its axial tilt is. But it's fairly safe to guess that its rotation is the same as its orbital period around Saturn: 15 days 22 hours 42 minutes. If this is true, Titan's poles would be inclined 90° to its orbit — which lies essentially in Saturn's equatorial plane.

Titan is a moon and so has no special symbol as the major planets do.

The Titans were 12 giants of classical mythology who warred against Jupiter and Saturn and were hurled into Tartarus. Their names were Oceanus, Coeus, Crius, Hyperion, Iapetus, Cronus (male) and Thia, Rhea, Themis, Mnemosyne, Phoebe, and Tethys (female).

Moons & Magnifications

Sir / While leafing through some back issues of ASTRONOMY, I found that Norman Butler made an interesting statement in the September 1980 issue. He pointed out that you can determine how far away the Moon (or any object) appears to be by dividing the actual distance by the magnification of your eyepiece.

I've taken this a step further. You can find out how big a planet appears from any of its moons by using a similar formula. Simply divide the distance from Earth to the planet by the distance from the planet to its moon.

For example, to find out what power you would need to enlarge Jupiter to the size it appears from Callisto, look up the distance from Earth to Jupiter (as listed in The Backyard Astronomer) — call it 5 A.U., or 465 million miles. Divide this figure by the distance from Jupiter to Callisto — about 1,170,000 miles. This calculates to a magnification of 397. Applying the method to other jovian moons, we find it would take only 32x for Sinope, Jupiter's farthest moon, and an astonishing 4135x for Amalthea, one of the closest.

Glenn Schuette
Universal City, TX

Asteroid Exchange

Sir / Regarding Mr. Teske's article, "Asteroid Collisions with Earth," ASTRONOMY, January 1982: The impact of such a body on Earth would have an even more devastating effect than the author describes. If military radar picked up an object entering the atmosphere, a nuclear attack would probably be presumed, and an immediate counterattack initiated.

This would obviously have a more drastic effect than the terrible — but localized compared to nuclear war — impact of an asteroid.

Mark Berry
Taylor, MI

Ooops!

In the constellation star map of Lepus in the January issue, the star marked R Leporis is actually R Eridani. R Leporis is the red star on the map that lies 16 millimeters to the upper left of the star circled.

behind
the scenes

the end of our role in deep space

The FY'83 NASA budget is a disaster for planetary science. It includes permanently shutting down probes already in space, dismantling much of the research effort that interprets data from Voyager and other missions, closing NASA's infrared telescope on Mauna Kea, and locking up the Apollo Moon rocks from further scientific study. Only the continuation of the phenomenally successful Voyager mission and a scaled-down Galileo mission remain.

What is happening? It appears that the Administration has accepted Presidential Science Advisor George Keyworth's recommendation that the American planetary program be dismantled. It also appears that NASA, the OMB, and the Adminstration are now moving to end U.S. involvement in the exploration of the planets as fast as is politically possible.

It may be that what remains of NASA's planetary program remains only because of the public outcry over the proposed elimination of the Voyager and Galileo programs. If so, ASTRONOMY's readers are to be congratulated for the concerted effort they have made on behalf of the space program. Your support, your letters to your Congressmen and Senators, your active participation in pro-space groups must continue, however, because without ongoing public pressure, budget cuts next year or the year after may result in the quiet cancellation of the few missions that remain.

Should you count on the cheap missions discussed in this month's feature article to "save" planetary exploration? Certainly not. They may never be funded if the planetary program itself is phased out.

In the face of the many other problems now facing the United States, it may seem out of place to put so much effort into exploring the solar system and the worlds beyond our own planet. Yet the cost is small compared to the sums we spend on nuclear armament. If you have never thought about nuclear war before, I urge you to do so, and to compare its benefits with the benefits we might expect to achieve from the scientific exploration of space.

Sincerely,

Richard Berry

Richard Berry
Editor

gazer's gazette

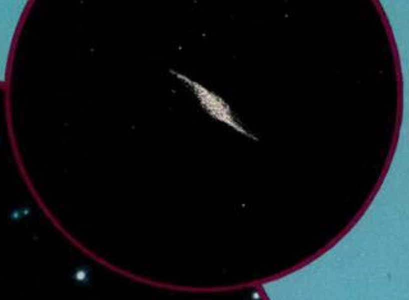
observing edge-on galaxies

by
Alan Goldstein

Hale Observatories photo of NGC-4565

NGC-4216
Photo by K.A. Brownlee

NGC-5907
Photo by Bill Iburg



NGC-253
Drawing by J. Mullaney

NGC-4631
Photo by Lee Coombs

NGC-891
Photo by Bill Iburg

If you are an avid sky watcher, you know that all galaxies don't look the same; some are long and thin while others are oval or even round. After observing them for several years, you get to know these distant celestial beacons simply from visiting with them whenever time permits. And by studying various catalogs while comparing the classifications with their appearance in your telescope, you can further sharpen your ability to identify various types of galaxies.

Edge-on galaxies appear the way they do because of our line of sight. We see them from the same plane as their equator, literally "edge-on," as the name implies. In the eyepiece they are distinct because they are so thin. They are also numerous, so you shouldn't have any difficulty finding them. In a photograph of the Hercules Cluster, for instance, you'll see many more edge-on than face-on galaxies.

But aside from being edge-on, these diverse masses of stars have little in common. Many factors affect how they appear in a telescope. Let's look at galaxy type, distance, presence and position of dust, and position of starclouds to see how these factors affect the appearance of edge-on galaxies.

Of course, the size of your scope has a lot to do with how the galaxy will look. Bigger scopes will show more detail. Eight to ten-inch apertures are good starting sizes although you can at least find the brighter objects with a smaller scope.

Spirals and lenticulars (Hubble type SO — see diagram on page 44), including barred varieties, have different edge-on appearances. Sa, SOa, SBa, and SBOa consist of a prominent central hub with very little arm or disk structure. When you view these galaxies edge-on, they are ovoid rather than flat and look a lot like a squashed football.

Sb, SOb, SBb, and SBOb galaxies have a balance between central hub and arm/disk structure. These appear rather flat, though their central hubs are still noticeable.

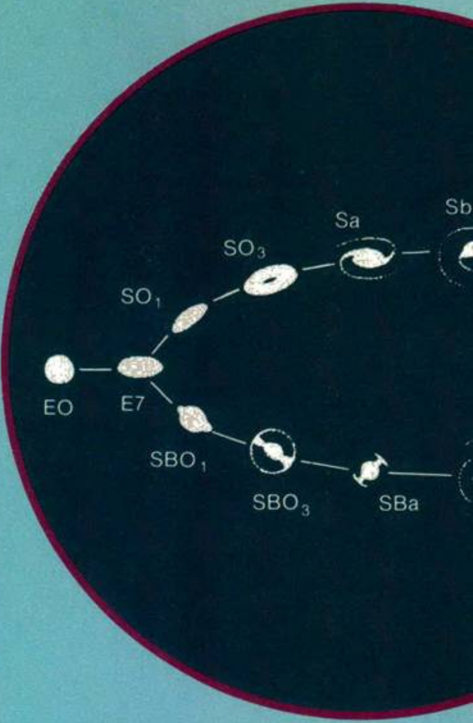
The Sc, SOc, SBc, SBOc, and types such as Sd and Sm have little or no central hub. The arm/disk structure is usually very flat — almost to the point of razor-thin when exactly edge-on. They are breathtaking in the field of a large aperture telescope.

All else being equal, the closer the galaxy is to us, the more detail you can see. But galaxies vary in both size and luminosity, and a nearby galaxy may

selected edge-on galaxies

Object (NGC)	RA (1950)	Dec	Mag.	Dia. (′)	e	Type	Description
24	00h07.4m	-25°15′	12.2	5x0.7	8.6	Sb	
55	12.5	-39 30	7.8	25x3	8.8	SBm	SC
134	27.9	-33 32	11.4	5x1	8.0	Sbc	
253	45.1	-25 34	8.9	24.6x4.5	7.8	S(B)c	SC, DP
681	01 46.7	-10 40	12.8	1.6x0.8	5.0	Sa	DL
891	02 19.3	42 07	10.9	11.8x1.1	9.1	Sb	DL
1337	03 25.6	-08 34	12.3	5.2x0.9	8.3	Sc	
1421	40.2	-13 40	12.0	3x0.6	8.0	Sb	
1448	42.1	-44 48	11.8	8x1	8.8	Sc	
1515	02.7	-54 14	12.1	6x1	8.3	Sb	
1532	10.2	-33 00	11.8	5x1	8.0	Sab	
2683	49.6	33 38	9.6	8x1.3	8.4	Sb	
3079	58.6	55 57	11.2	8x1	8.8	Sb	
3203	10 16.3	-26 27	13.2	2x0.3	8.5	SO	
3432	49.7	36 54	11.4	5.8x0.8	10.0	Scp	
3448	51.7	54 34	11.7	1.8x0.3	8.3	Sbp	
3556 M-108	08.7	55 57	10.7	7.7x1.3	8.3	Sc	SC
3623 M-65	16.3	13 23	9.3	7.8x1.5	8.1	Sb	
3628	17.7	13 53	10.9	12x1.5	8.8	Sb	DL (assym.)
3877	43.65	47 46	10.9	4.4x0.8	8.2	Sb	
3936	49.9	-26 37	13.0	3.3x0.3	10.0	Sb	
3956	51.6	-20 18	12.6	3.2x0.5	8.4	Sc	
4026	56.9	54 14	10.7	3.6x0.7	8.1	SO	
4096	12 03.5	47 45	11.9	5.7x1	8.2	Sc	
4111	04.5	43 21	9.7	3.3x0.6	8.2	SO	
4128	06.1	69 03	12.3	1.6x0.4	7.5	Sa	
4144	07.5	46 44	12.4	5.2x0.7	8.7	Sb	
4157	08.6	50 46	11.9	6.5x0.8	8.8	Sb	
4160	09.1	44 01	12.6	.4x0.4	9.1	S	
4217	13.3	47 22	11.9	4.5x0.9	8.0	Sb	
4216	13.4	13 25	10.4	7.4x0.9	8.8	Sb	~DL
4235	14.6	07 28	12.6	2.6x0.5	8.1	Sa	
4244	15.0	38 05	11.9	14.5x1	9.3	Sc	
4302	19.2	14 53	12.4	4.7x0.5	8.9	Sc	
4388	23.2	12 56	11.7	5x0.9	8.2	Sb	
4517	29.0	00 21	12.0	8.9x0.9	9.0	Sc	
4594 M-104	37.3	-11 21	8.7	6x2.5	5.8	Sa	DL, nucleus
4565	12 33.9	26 16	10.2	14.4x1.2	9.3	Sb	DL
4631	39.8	32 49	9.3	12.6x1.4	8.9	Sc	SC, DP
4656	41.6	32 26	11.2	19.5x2	9.0	Scd	SC, warped
4700	46.5	-11 08	12.2	2.2x0.3	8.6	SB	
4710	47.1	15 26	12.0	3.3x0.5	8.5	SO	DL
4762	50.4	11 31	11.0	3.7x0.4	8.5	SOc	
4845	55.5	01 51	12.6	4.2x0.7	8.3	Sb	
4866	57.0	14 27	11.4	6.8x0.8	8.8	Sa	
4945	13 02.4	-49 01	9.2	11.5x2	8.3	Sc	SC
5084	17.5	-21 34	12.4	6.6x1	8.5	SO	
5170	27.1	-17 42	12.6	7.6x0.7	9.1	Sc	
5297	44.3	44 05	12.0	5.2x0.8	8.5	Sb	
5377	54.3	47 27	11.2	3x0.6	8.0	Sap	
IC 4351	54.9	-29 05	12.8	5x0.5	9.0	Sb	
5422	59.0	55 24	11.5	2.9x0.4	8.6	Sa/SO	
5746	42.3	02 10	10.1	6.2x0.8	8.7	Sb	
5775	51.5	03 45	12.2	3.6x0.5	8.6	Sb	
5866	15 05.1	55 57	10.8	2.8x1	6.4	SOa	DL
5854	05.3	02 45	12.6	1.8x0.4	7.8	SBa	
5907	14.6	56 31	11.3	11.1x0.7	9.4	Sb	
IC 5052	20 47.5	-69 25	12.3	6x0.8	8.6	Sd	
7090	32.9	-54 47	11.8	6x1	8.3	SBc	
7184	59.9	-21 04	12.0	5.1x0.9	8.2	Sb	
7456	22 59.3	-39 51	12.5	6x1	8.3	Sc	
7582	23 15.8	-42 38	11.8	3x0.5	8.9	Sb	
7640	19.7	40 35	11.3	11x1.4	8.7	SBb	
7814	00 00.7	15 51	12.4	3x0.8	7.3	Sa	DL

e = ellipticity. Figured by: 10(a-b) / a. (a = major axis, b = minor.)
The closer e is to 10, the more elongated the galaxy appears.
SC = Star Cloud DP = Dark Patches DL = Dark Lane



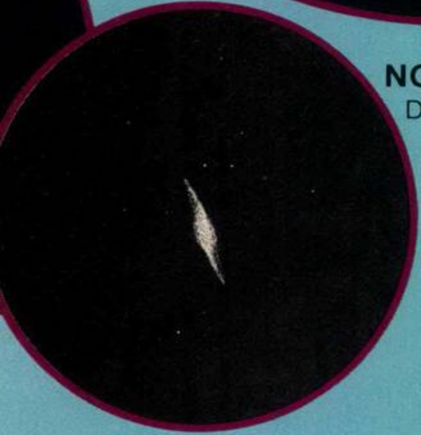
NGC-4244
Photo by K.A. Brownlee

NGC-4157
Photo by K.A. Brownlee

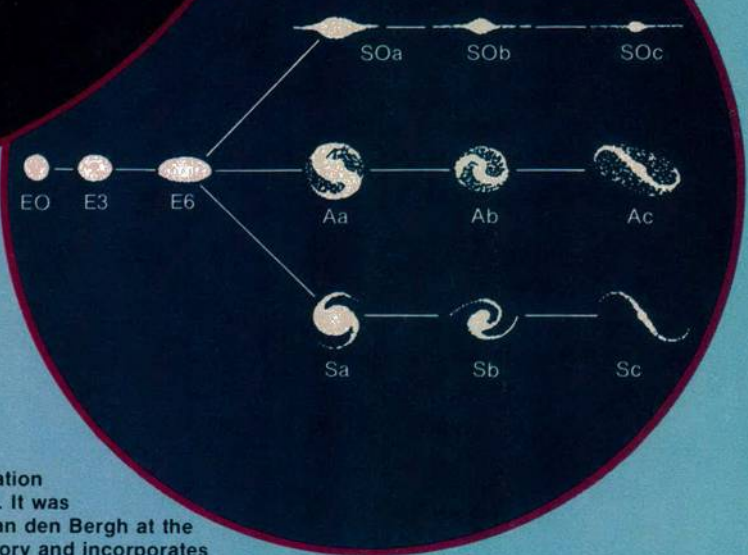
At left is Edwin Hubble's "tuning fork" diagram. Introduced in 1936, it is the most widely used classification scheme for galaxies and shows the progression from a smooth featureless galaxy to more evolved ellipticals and spirals.

NGC-4565
Photo by Bill Iburg

NGC-253
Photo by Greg Griffith



NGC-4565
Drawing by
J. Mullaney



At right is a contemporary classification system called the DDO. It was developed by Sidney van den Bergh at the David Dunlap Observatory and incorporates features of the Hubble system with newer information. ©1976 by the American Astronomical Society not be brighter than a more distant one. If your scope is big enough, though, you can observe structural detail. More often than not, the smaller, fainter galaxies are more distant. Of course, by knowing in advance which objects you intend to observe, you can look up their distances.

Perhaps the most striking visual aspect of an edge-on galaxy is a belt of dust girdling its equatorial plane. If the dark lane is off-center or asymmetrically thick, the galaxy is even more intriguing. NGC-891, NGC-4565 and M-104 are among the best examples of belted spirals.

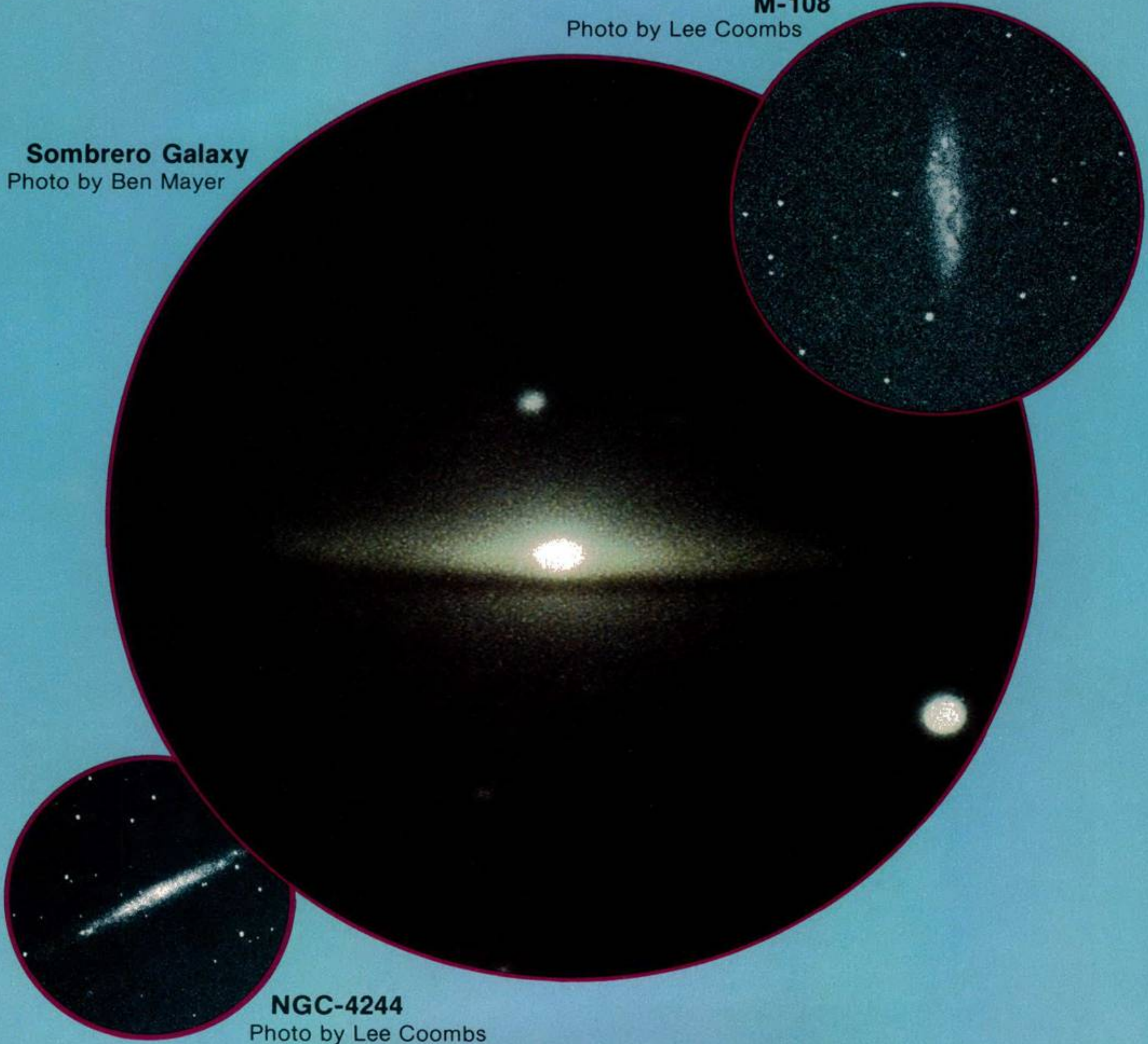
A patchy appearance or uneven illumination is a dead giveaway of starclouds or H-II regions in an Sc galaxy. As you might expect, only nearby galaxies show these features in moderate instruments. NGC-55, M-108 and NGC-4631 are among the best examples.

Since true edge-on galaxies show an equator, their cores are usually invisible, hidden behind many kiloparsecs of arms or disk. If a galaxy is slightly tipped from 90°, you might be able to glimpse the nucleus — if you have a large enough scope. The Sombrero Galaxy, M-104, is a dramatic example. In the latest-type spirals, where little or no nucleus is present, you won't be able to see much more than a central brightening.

Edge-on galaxies show the "true" galactic shape better than any others. With a little experience you can accurately determine their type by comparing the size of the central bulge, or hub, to the length of the arms. The outermost tips of the arms may be too faint for you to discern — especially if you are used to seeing them in photographs — so the galaxy in question might be listed other than how you see it. Not all edge-on galaxies are perfectly straight; some are warped by tidal interactions with other galaxies and appear curved at one or both ends.

Edge-on galaxies are not clustered in any particular part of the sky, and on most nights of the year you can see at least a few. Start with a star chart such as *Sky Atlas 2000.0*; then you can find your galaxies by star-hopping. Once you get a few under your belt you might find yourself devoting more and more time at the eyepiece to hunting down these distant beacons.

Alan Goldstein is a student at the University of Louisville, Kentucky. His last article for ASTRONOMY, "Observing Peculiar Galaxies," appeared in February 1981.



M-108
Photo by Lee Coombs

Sombrero Galaxy
Photo by Ben Mayer

NGC-4244
Photo by Lee Coombs

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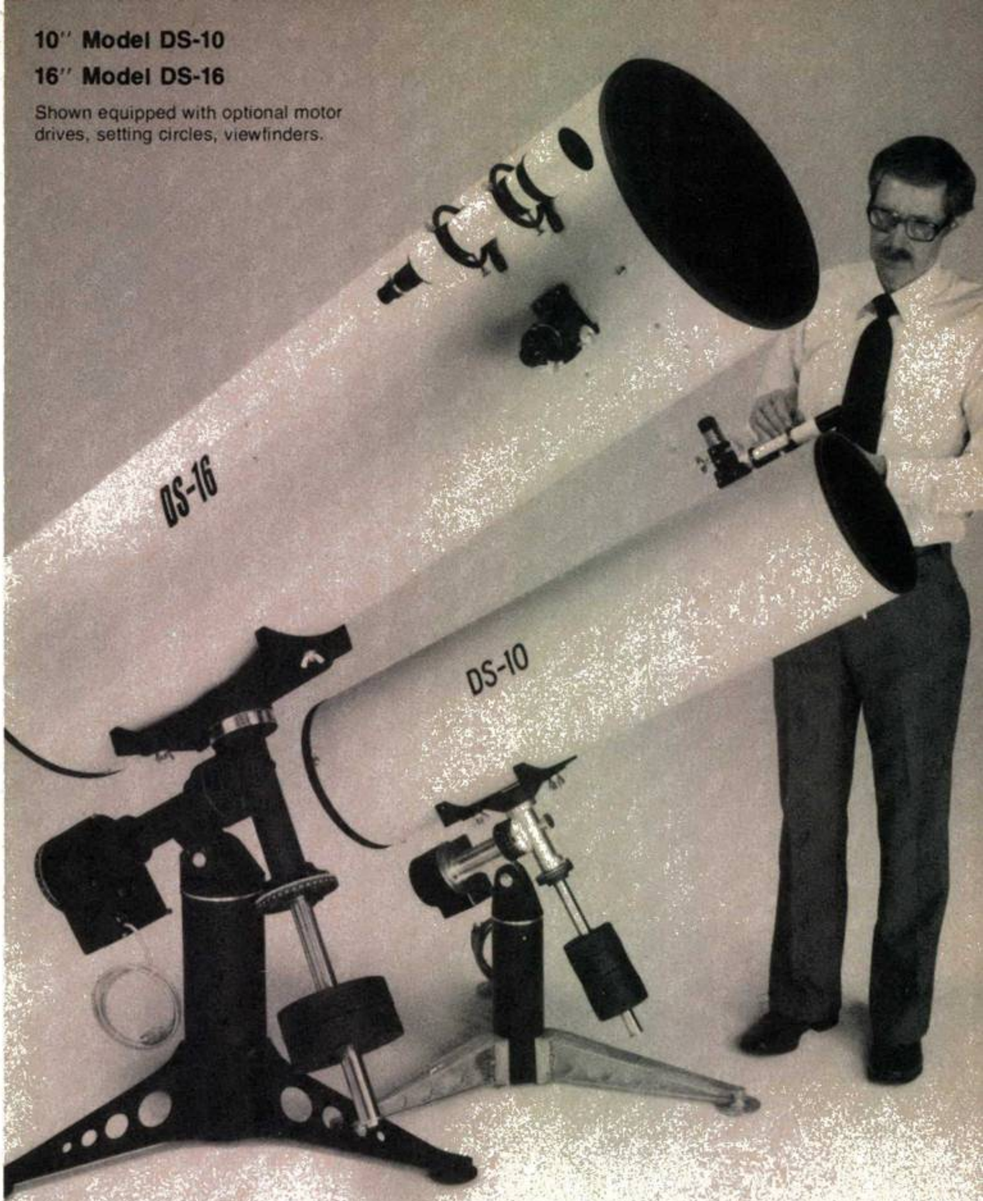

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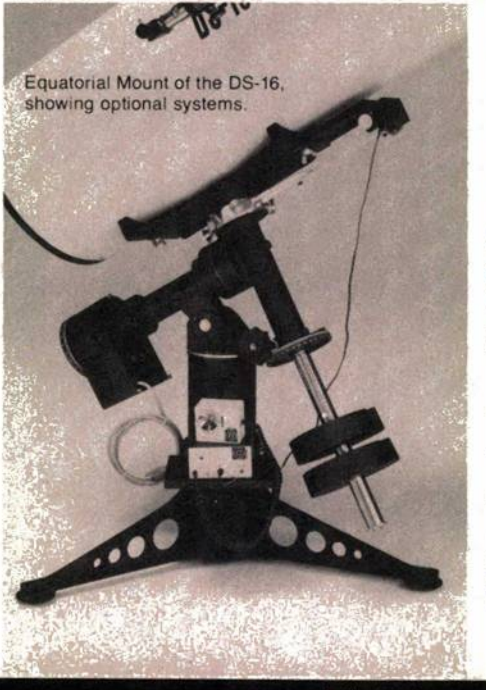
Equatorial Mount of the DS-16, showing optional systems.

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27— **GIANT 9×60mm|RIGHT ANGLE—$71.50 ppd;** Brackets: **$12.50/pr.**

28—**RESEARCH-GRADE ERFLE 32mm EYEPIECE (2" O.D.; MULTI-COATED)**—Wide-angle, fully-corrected 65° field. The finest eyepiece obtainable in 2" barrel. **$89.50 ppd.** Adapter Barrel for 1¼" O.D. **$10.75 ppd.**

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36—**ERECTING PRISMS**—Fully coated Porro prisms. Invert the astronomical image for terrestrial observations with astronomical telescopes. **1¼" O.D. . . . $29.75 ppd.; .965" O.D. . . . $25.75 ppd.**

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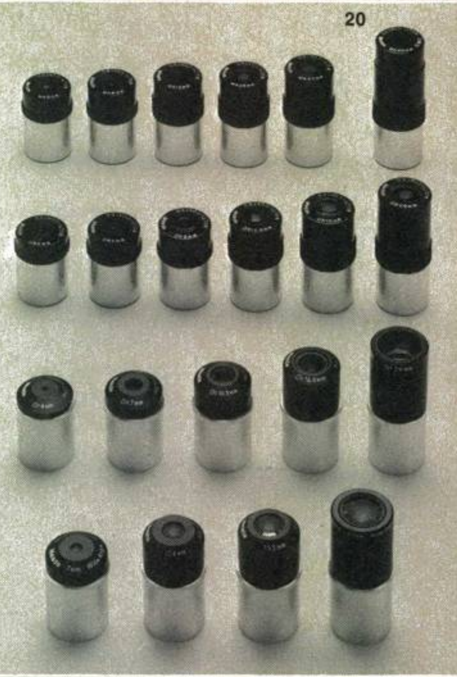

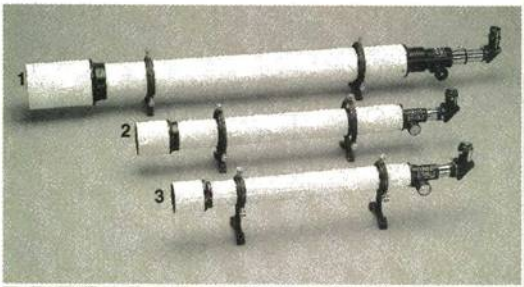

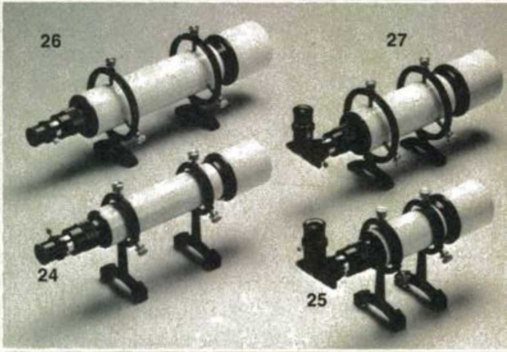

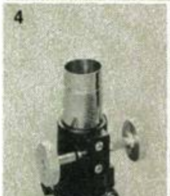
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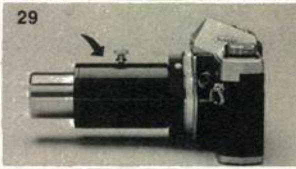
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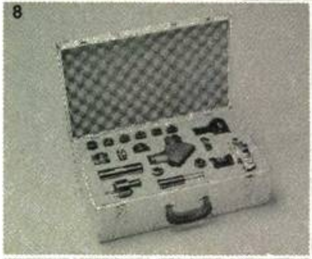
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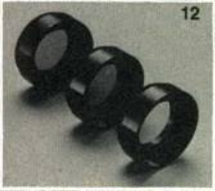
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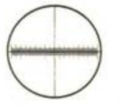
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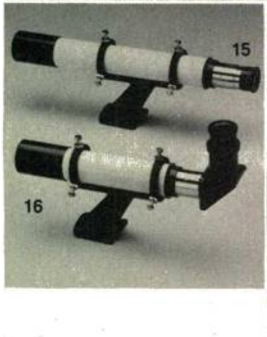

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Meade Model 2080:
8" Schmidt-Cassegrain

Meade Model 2120
10" Schmidt-Cassegrain

Shown with optional equatorial wedges, field tripods, and astrophoto equipment.

Model 2120
Model 2080

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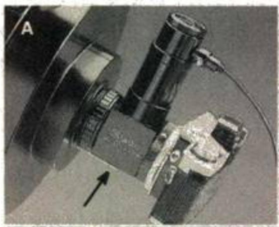

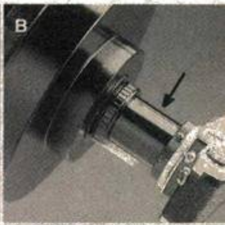

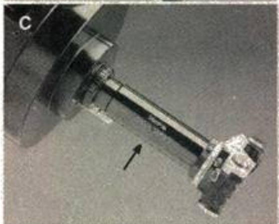

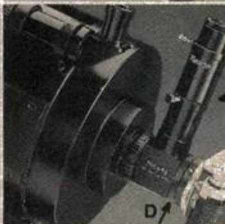

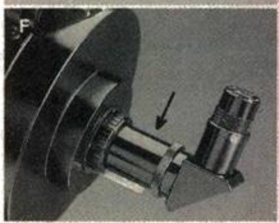

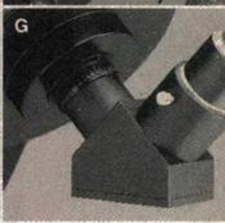

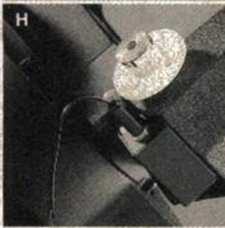

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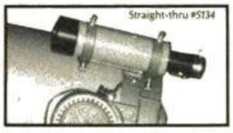

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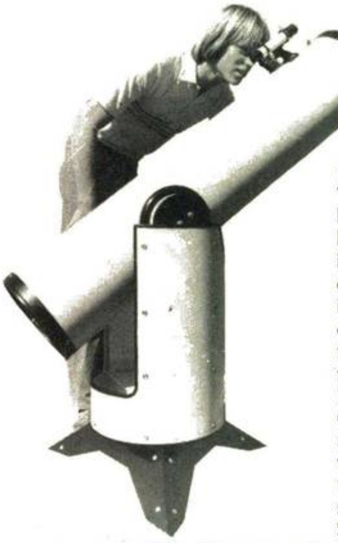

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astrophotography grab-bag | photography in astronomy

portable astronomy

by Howard Lazerson

Have you ever wanted to pack up your scope and take it on a vacation with you — or maybe just get out under the stars — without having to fuss with setting up your main instrument? It seems like there is always time for a little bit of observing, but never quite enough to get out all your equipment.

If time constraints hit you square in the face and you've spent a lot of money on all kinds of gadgets, then maybe returning to the basics would be a refreshing change. And if you haven't yet decided what kind of telescope you want for the rest of your life, you might try this simple solution.

Get yourself a small, light telescope such as a rich-field refractor that uses a 3-inch lens and cell mounted in an aluminum tube. It makes a good visual and photographic setup. Since it is easy to use, and lacks fancy accessories, you can concentrate on the basics of observing.

A complete telescope like this, with eyepiece, will weigh in at a feathery 2¾ pounds and is only 11½" in length. You can use it hand-held for rich-field scanning, or mounted on a simple wooden fork.

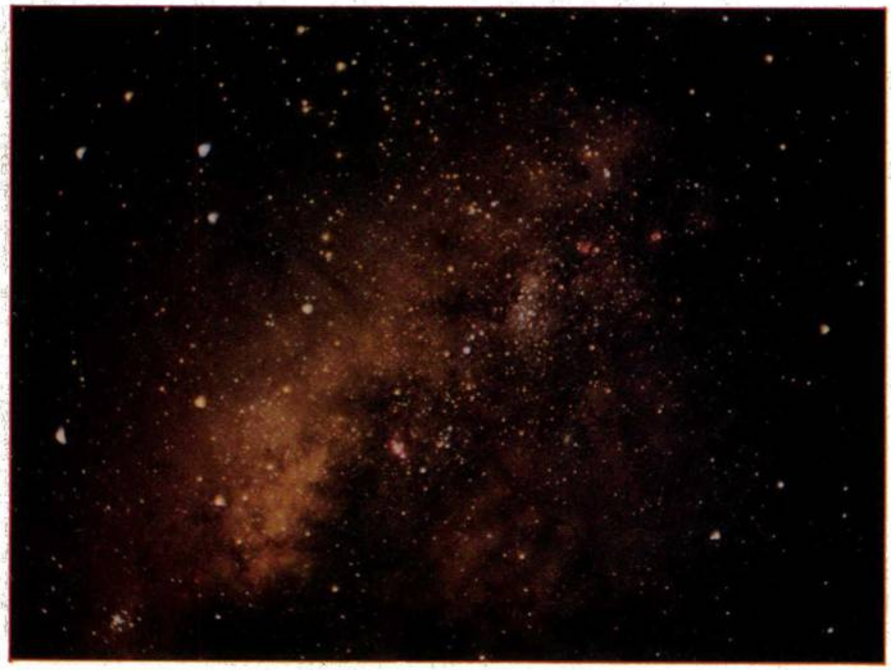
Then, to set it up for photography, you can put it on a small, modified refractor mounting — the kind with manual slow motion controls. You don't even need a clock-drive. Though this system is small in aperture, it has all the ingredients of a visual-photographic system — at minimal expense. If your interest continues, the experience you gain with this setup will help you make a wiser choice for a second telescope. At the very least, you still have a small scope that is perfect for terrestrial spotting.

This system is both easy and satisfying to use. You can carry the entire telescope, mount, counterweight, and your camera in one hand. Viewing is comfortable since you can observe in a sitting position. You don't need any external power or batteries either, because you can guide very well by using the manual slow motions provided on the mounting — just use an out-of-focus guide star and simple cross hairs. The scope will also be more than adequate as a guiding instrument for the wide fields of most camera lenses. With today's fast films, or commercially available sensitized film, you will have a very pleasant introduction to astrophotography — all without complicated equipment.

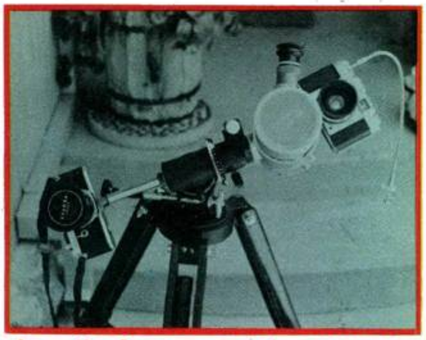
Visually, the telescope works best with a low-power eyepiece — such as a 32mm Erfle. At this magnification your telescope is its own finder and operates as an RFT for clusters, galaxies, or comets. Adding a Barlow lens or a higher-power eyepiece allows you to study lunar and planetary detail.

For traveling, build a set of short tripod legs that fit together with the mount in a small suitcase. Pack the telescope and camera into a foam-lined fishing tackle box which will fit under commercial airline seats. You can now take the entire outfit to dark-sky vacation sites where you can observe and photograph at your leisure.

Setup is simply a matter of bolting on the tripod legs, clamping the telescope



This 10-minute exposure of the southern Milky Way in Sagittarius was taken with the camera set-up described by Howard Lazerson. He used a 50mm f/1.4 lens and unhypered Fujichrome R-100 film.



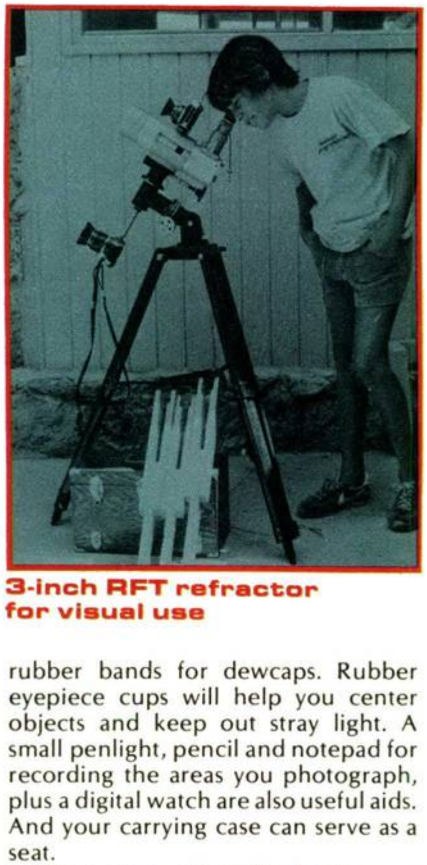
detail of camera placement

in its cradle, and screwing in the cameras. This way you spend more time observing and less time setting up.

Finding a bright guide star for the non-illuminated cross hairs is no problem since the cameras are easy to rotate to an off-axis position. The accessory camera mount on the cradle lets you use two cameras at once so you can photograph with different films or focal lengths. You'll also be able to photograph different areas simultaneously.

Keep accessories and their costs to a minimum and you'll enjoy your outings even more. You can use sheets of black construction paper and rubber bands for dewcaps. Rubber eyepiece cups will help you center objects and keep out stray light. A small penlight, pencil and notepad for recording the areas you photograph, plus a digital watch are also useful aids. And your carrying case can serve as a seat.

This system offers the beginner a good compromise in terms of aperture and ease of use versus bulk. Mine has logged over 65,000 miles by airplane, car, and boat without any serious damage.



3-inch RFT refractor for visual use

making black and white slides

by Chris Callahan

Printing black and white astrophotos is a hassle. All that burning and dodging you have to do to preserve the subtle details on the negative seems like more trouble than it's worth. Not to mention the problems with passing them around at the club's monthly meeting.

Surely there is a better way to protect and display your good astrophotos without running the risk of having them lost or damaged. Why not make black and white slides from those negatives? Then you'll be able to store them much easier — since they take up less room than 8x10s — and simplify how you display them. Just put them in a projector and amaze everyone with the detail you recorded through that 6-inch.

The idea behind the process is simply to copy or print a negative onto another piece of film to produce a positive, or transparency, you can project. Eastman Fine Grain Positive Release Film 5302 is a good duplicating film to use. You can find it in most photo stores either in 35mm size, or 100 foot rolls. You will also need a supply of slide mounts.

You can choose from two common methods for producing transparencies: contact printing or slide copying. But remember, positive release film is slow, so you'll have to expose it for several seconds.

In the contact printing method, place the negative and the positive film emulsion-to-emulsion with the negative on top. Cover both with a sheet of very clean glass to maintain close contact during the exposure. You can use any convenient light source.

Perhaps the best method is to load the positive release film into cassettes and use a slide copying attachment on a 35mm camera. This technique produces good results with a copying ratio of one-to-one, and a BBA-No. 1 photoflood lamp about two-and-half-feet in front of the copier. The lamps are sold in most camera stores.

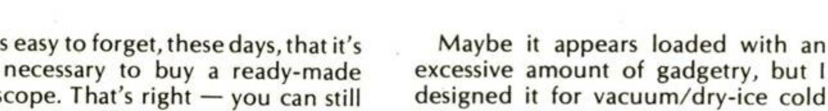
Set the lens at f/16 to insure good sharpness. At this setting you'll need an exposure from four to six seconds. Of course, any copying arrangement can work. Keep in mind that exposure times will vary depending on the density of the original negative, and make additional shots changing the exposure time by several seconds. The film is inexpensive and the extra exposures will pay off later by providing one that is properly exposed.

You can process positive release film in several different developers depending on how much contrast you want — instructions come with the film. However, Kodak D-19, which is not listed in the instructions, also works very well with a development time of six minutes at 68°F.

After processing and drying, all you have to do is place the film in slide mounts. Both plastic and cardboard mounts offer some advantages — plastic mounts are easier and faster to load, resist warping, and are reusable. But you can write on cardboard mounts, and they also hold the film flatter. Just make sure you carefully insert the individual frames into the mounts.

If you follow this easy process, you will be able to make high quality black-and-white slides from any negative you have. And you won't lose the faint details you would if you printed them.

contact printing



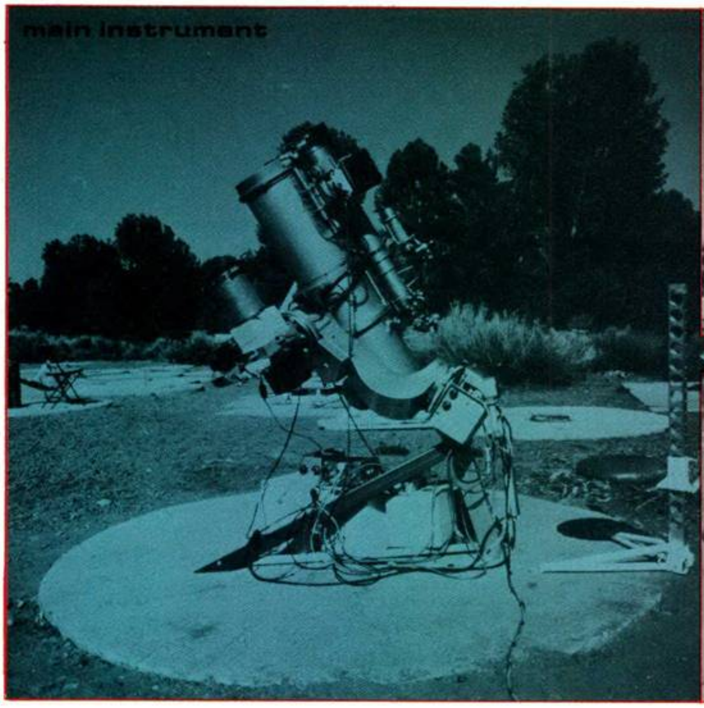
an 8-inch telescope for astrophotography

by Orien Ernest

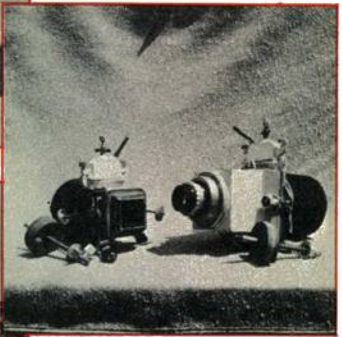
It's easy to forget, these days, that it's not necessary to buy a ready-made telescope. That's right — you can still "do-it-yourself" in astronomy and build an instrument suitable for really fine deep-sky photography. I finished my latest telescope, an 8-inch f/5, about two years ago. It is the fifth telescope I have built in the last 18 years.

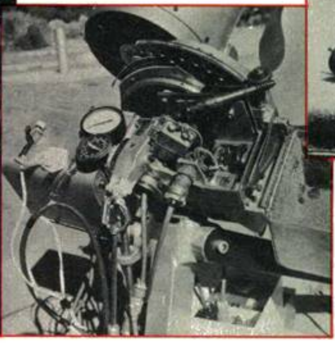
Maybe it appears loaded with an excessive amount of gadgetry, but I designed it for vacuum/dry-ice cold

When you design a telescope specifically for astrophotography, your photos should come out pretty good. This is a 30-minute exposure of M-8 and M-20 using dry-ice cooled Ektachrome 400 and the telescope and camera described by Orien Ernest.


main instrument

guide and finder scopes


dry-ice cold camera


gear system

camera astrophotography (see "Cold Cameras, Parts 1 and 2," February and March 1977), and there is nothing on it that I don't use.

Let's start with the basics of the design: the mount. I chose a one-arm fork mount because this type is easier to operate than a two-arm fork or German mount. The fork is supported on sturdy bearings and the whole scope rests on a short tripod of heavy-wall tubing. Most of the material in it is aluminum — I buy scrap material, cut the parts out, weld them, then file and fill the parts.

You need a good guidescope for astrophotography. My 8-inch carries a 4-inch f/8 refractor piggyback. The front end rests in a solid swivel mount and the back is held by two adjustable rods. This lets me find a guide star easily and lock onto it. With two turret-mounted eyepieces, one low power for finding the star and the other high power for guiding, the 4-inch makes a nearly ideal guider.

Drives are also important for long-exposure photography. Both polar and declination axis shafts are driven by 5.9-inch radius good-quality worm gear sectors. The sector on the polar axis can drive the telescope for six hours before I have to reset it. To keep good contact, the worm that drives the gear is loaded against it by spring tension. This prevents backlash and gear play.

The polar axis has a two-motor drive system. The main drive motor is a 120-volt synchronous motor that turns the drive at a constant speed. A 24-volt, reversible, variable-speed DC motor designed for aircraft use provides slow motion control. I connected the shaft of the 24-volt motor into the main drive system through a differential gear so if the motor turns clockwise or counterclockwise, it adds or subtracts speed from the drive.

For slewing, the 24-volt motor can drive the telescope at more than three times tracking speed, but at low speed, it can make delicate rate corrections.

The declination axis also uses a worm gear drive — a 24-volt motor similar to that on the polar axis drive. This motor handles guiding corrections and drives the declination axis more than three times tracking speed for centering objects. Both polar and declination drives are controlled from a hand-held control stick.

The synchronous drive motor receives its power from a 12-VDC/120-VAC variable frequency inverter powered by an automobile battery. Both DC motors receive their power from a transformer-and-rectifier power supply that gets its power from the inverter.

Now for the photographic part. The cold camera interchanges with the eyepiece focuser. This camera holds 2" x 2" films cooled to dry ice temperatures. The cold eliminates much of the film's reciprocity failure, so it performs much better than warm film. But the lower temperature also causes a problem, because water will condense on the -40° C emulsion surface. To cure that, I keep the film in a vacuum chamber with a 3/16" thick glass window on the front. The vacuum also improves the film speed by drying it. To prevent dew forming on the window, however, I must heat it with an electric soldering iron heating element just enough to keep it dry.

The film is cooled from behind by dry ice (frozen CO_2). A metal chamber holds a charge of dry-ice sufficient to cool the camera for five hours after loading. For the vacuum, I use a small reciprocating vacuum pump that pulls ½" of mercury and draws only 25 watts of power.

I mount two other cameras on the end of the declination shaft, opposite the telescope. One is a 2¼" x 3" film dry-ice camera attached to an 8.5-inch focus f/4.5 lens. It is similar in design to the camera for the main telescope. The other camera uses 2¼" x 2¼" film with an 80mm f/2 lens and gives a wide field of view.

All three cameras have pneumatic shutters. I control them with a small hand pump, so I don't have to stumble around in the dark opening or closing shutters to start and stop the exposures. It's also handy since I can stop them immediately if somebody's auto headlights come too close.

Recently, I've started using hypersensitized film in the 2¼" x 2¼" camera. This allows me to stop down from f/2 to f/4, and get a very sharp image on Ektachrome 400 film. I have tested a good number of hypersensitized color films, but none equal the results of the dry-ice system in exposure or color quality. However, I believe that hypered color film is the next best thing to cooled-emulsion photography.

Loading, transporting, and setting up all the extra equipment for the dry-ice cameras is quite a chore, but since quality is very important to me, and since I haven't found a good alternative to cooled-emulsion photography, I will very likely continue to use dry-ice until I find a better process.

astro-sources | equipment atlas

"Where will Mars be on October 10th?" "How long is a tropical year?" "How fast is the Andromeda Galaxy moving relative to us?" If you're like most people with an interest in astronomy, questions like these will occur to you from time to time. Old hands usually know where to look up the answers, but for many beginners, the literature of astronomy seems so vast and so forbidding that they don't know where to start.

Therefore, we have prepared a sort of "Whole Universe Catalog," which will tell you what the basic sources of astronomical information are, and what they contain. We haven't listed books *about* astronomy, or even every good book on astronomy, since there are far too many to squeeze in. Instead we've concentrated on those invaluable reference sources of astronomical facts. This list ought to get beginners pretty well oriented. Most of the items can be bought or ordered through a book dealer and many are available in large public or college library collections. Those also available from ASTRONOMY carry an asterisk.

In addition, don't overlook the possibilities of used and second-hand book shops. They're fun to poke around in and it's a rare shop where you won't turn up a bargain or two.

Of all the reference books on astronomy, perhaps the one most commonly used is the **Astronomical Almanac**. This is published each year by the U.S. Naval Observatory and Britain's Royal Greenwich Observatory and is sold by the U.S. Government Printing Office.

The *Almanac* provides position predictions for the Sun, Moon, all the major planets, and the largest four asteroids (Ceres, Pallas, Juno, and Vesta). A page of it looks rather like the telephone book — with rows and rows of numbers. In addition to the positions, usually given at daily intervals, it also provides tables of "physical data" — including apparent sizes, magnitudes, and elongations of planetary satellites. For anyone with access to a computer, most of the *Almanac*'s data are given in "do-it-yourself" form in the **Almanac for Computers**, a 64-page softcover book available from the U.S. Naval Observatory.

Two other annual publications are the **Observer's Handbook** published by the Royal Astronomical Society of Canada, and the **Handbook** of the British Astronomical Association. Though they differ substantially in format, both of these handy volumes contain much of the same information and serve as a "digest" of the *Astronomical Almanac*.

M-51 by Howard McCallon

The *Observer's Handbook* contains a section that gives day-by-day events. The B.A.A. *Handbook* is arranged by object — Venus, the Sun, Jupiter, and so on. Both contain tables such as dates of meteor showers and the brightest stars of the sky. These ancillary tables are more complete in the *Observer's Handbook* and, in addition, its listings of lunar occultation dates, times, and locations are more useful, since they are intended for the North American viewer.

Guy Ottewell's annual **Astronomical Calendar** is a large-format, softcover book which provides a two page spread for each month's events. On the left page is a simple star map — on the right, a day-by-day calendar of events. In addition, he provides a substantial amount of explanatory material, both text and diagrams.

The next most useful item is a star atlas: several good ones are on the market. Handily wire-bound is the **Mag 6 Star Atlas** [Edmund Scientific] which covers the entire sky in 12 charts and plots stars down to 6th magnitude. Three areas of special interest where objects crowd together closely — Orion, the Virgo-Coma cluster of galaxies, and Scutum-Sagittarius — are shown in greater detail in additional charts. The coordinate epoch is 1950.0, but for most purposes this will present little problem. There is a detailed introductory section on observing.

Similar, but more expensive, is **Norton's Star Atlas** [Sky Publishing]. *Norton's* covers the sky in 9 charts, plots stars to magnitude 6, and has a coordinate epoch of 1950.0. There is a lot of prefatory material on the care and use of telescopes.

Wil Tirion's **Sky Atlas 2000.0*** [Cambridge University Press] is more detailed. Like *Norton's*, it also covers the entire sky, but uses 26 large charts and shows stars to 8th magnitude. As its name suggests, the coordinate grid is for the epoch 2000.0. (This is closer to the present day than *Norton's* 1950.0, but of little importance in most observing.) In addition, the atlas shows many more galaxies, nebulae, and star clusters than does *Norton's*. It is available in a full-sized color edition, and reduced size field and desk editions.

A star catalog is a useful companion to any star atlas because it lists data on objects plotted. The *Mag 6* and *Norton's* have no accompanying catalog, but Webb's *Celestial Objects for Common Telescopes* works well. For the *Sky Atlas 2000.0*, the most useful catalog is the **Sky Catalog 2000.0** [Cambridge University Press]. As yet only the stellar volume has been published; it provides positions, magnitudes, distances, spectral types on 43,000 stars down to 8.05 magnitude. The rest of the catalog, with data on nebulae, clusters, and galaxies, is to follow soon.

Since observing is one of those learn-by-doing types of activity, a guidebook that distills the experiences of others can be a great help to a beginner. One of the best known such guides is Thomas W. Webb's **Celestial Objects for Common Telescopes***.

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Variable Star Observers
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Cambridge, MA 02138

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and Planetary Observers
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University Park, NM 88003

Astronomical League
Roger Kolman
3229 N. Orange Ave.
Chicago, IL 60634

British Astronomical Assoc. and
Royal Astronomical Society
Burlington House
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Canada

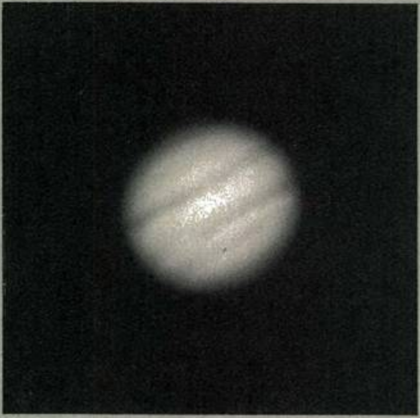
First published in 1859, Webb's book has been updated many times. The current edition, available from Dover Publications, is a partial revision of the 6th edition, published in 1917. The Dover revision was only partial because the first of the book's two volumes — on the solar system — naturally reflected only what was known in 1917 and would have needed a complete rewrite. By comparision, the second volume — on deep-sky objects seen in constellations visible from middle-northern latitudes — was less out of date and required fewer changes. Despite its hoary age, many telescope owners cherish their copies of Webb's book — if only because it conveys so well the flavor of a bygone era in amateur astronomy.

A more recent guidebook, one limited to deep-sky objects alone, is the three volume **Burnham's Celestial Handbook*** by Robert Burnham, Jr. [Dover]. A staff member at Lowell Observatory, Burnham has compiled a work that lists, constellation by constellation, all the bright objects — and a good number of the faint ones — all over the sky. For the more notable objects, he provides an extended discussion about special features.

A handbook of another type is the **Complete Manual of Amateur Astronomy** by P. Clay Sherrod [Prentice-Hall]. This differs from the above two books in that it doesn't provide any lists of objects to observe. Instead, it gives advice on how to use your equipment to make precise, "scientific-quality" observations. It is similar to an older and slightly more technical work, **Observational Astronomy for Amateurs*** by J. B. Sidgwick [Dover].

Besides these general guides, several specialized books are available. Consider, for example, the famous "Messier list," a catalog of some 100-plus non-stellar objects that was compiled for reference use by Charles Messier, an 18th century French comet hunter. To avoid false alarms, he made a list of the objects that looked like comets but weren't. Since his list includes many of the bright and beautiful nebulae and galaxies in the sky, its members are favorites to many telescope users.

One of the best guides to the Messier list is now out of print, but usually available in large libraries: Kenneth Glyn Jones' **Messier's Nebulae and Star Clusters**. In print is **The Messier Album*** by John Mallas and Evered Kreimer [Cambridge University Press]. Both works provide finder charts and show sketches of what the objects look like in the eyepiece. The discussion of each object in the Glyn Jones book is more complete, but the Mallas and Kreimer work provides a photograph. Both have long and well-written introductions.



Jupiter by Brian Tkachyk

Another, and far more lengthy, listing of deep-sky objects is the **New General Catalogue**, usually known simply as the *NGC*. The *NGC* proper was published in 1888, and two supplementary *Index Catalogues* followed in 1895 and 1908. The total number of objects listed in all three comes to over 7800; most of them are galaxies, though there is a substantial number of clusters and nebulae.

A reprint of the original three lists is available from the Royal Astronomical Society, and the University of Arizona Press has published a **Revised New General Catalogue** by Jack Sulentic and William Tifft. Both the *NGC* and the *RNGC* give positions, notes on the objects, and descriptions. (The *RNGC* also has magnitudes and galactic coordinates.) One annoying drawback to both works is that the descriptions of the objects are given in a highly abbreviated, hence extremely cryptic, code. **Deep Sky Monthly** is a little magazine devoted to deep sky observers, and features articles on observing, galaxies, nebulae, and double stars. A general work on the Milky Way Galaxy — and, by extension, other galaxies — is Bart and Priscilla Bok's **The Milky Way** [Harvard University Press].

Sunspot group by Jean Dragesco

Curiously, general works on solar system observing are scarce. To some extent, this is compensated for by large sections in the Sherrod and Sidgwick books mentioned before. (But be aware that much of the data in the latter are badly in need of updating because of spacecraft findings.)

For a factual look at the solar system, two titles worth picking up are **Moons and Planets** by William K. Hartmann and **Earthlike Planets*** by Bruce Murray, Michael Malin, and Ronald Greeley [W. H. Freeman]. The Hartmann book was published in 1972 and is out of date in some specifics, though its "holistic" approach to the solar system is superb. *Earthlike Planets*, as the title suggests, covers only the terrestrial worlds, but is a good, up-to-date work on comparative planetology.

A worthwhile out of print title on

solar observing is William Baxter's **The Sun and the Amateur Astronomer**. He covers the basic techniques for both making sketches and taking photographs and provides information about the Sun to put the observations into context.

The face of the Moon has long attracted telescope users, and numerous guidebooks have been written about its topography. Unfortunately, many of the best are out of print. Titles to look for in a library are: **The Moon** by E. Neison (1876), **The Moon** by H. P. Wilkins and P. Moore (1955), and **Moon, Mars and Venus*** by A. Rukl (1976). All of these feature hand-drawn maps of the Moon and discussions of many of the features visible in medium and large-size telescopes. The first two have very extended descriptions, though the maps are a little crude; the last has excellent maps, but only perfunctory descriptions.

Three photographic lunar atlases are **Lunar Atlas** by Dinsmore Alter, **Lunar Orbiter Photographic Atlas of the Moon** by D. E. Bowker and J. K. Hughes, and the **Atlas and Gazetteer of the Near Side of the Moon** by G. L. Gutschewski, D. C. Kinsler, and E. Whitaker. The first has an excellent selection of Earth-based photographs accompanied by a good, though pre-Apollo, descriptive text; the others have photos taken by the unmanned Lunar Orbiter space probes.

The **Times Atlas of the Moon** is a cartographic lunar atlas. Now out of print, it consists of the 1:1,000,000 scale lunar charts prepared by the U.S. Air Force in the 1960s, bound into book form. The maps, based on observations made from Earth, have shaded relief and contour lines, and are very detailed.

Two of the outer gas giant planets are featured, respectively, in Bertrand Peek's **The Planet Jupiter** and A. Alexander's **The Planet Saturn**. *Jupiter* is available from Faber and Faber, *Saturn* from Dover. *Jupiter* is arranged by topic — rotation period, belts and zones, satellites, and so on — while *Saturn* gives a history of the planet's observations, starting with the earliest recorded sightings that have survived from antiquity, and carries the story down to 1960.

For Pluto, the best recent titles are Anthony Whyte's **The Planet Pluto** [Pergamon Press], **Out of the Darkness** by Clyde Tombaugh and Patrick Moore [Stackpole Books], and **Planets X and Pluto** by William Hoyt [University of Arizona]. All three deal with the searches for planets outside the orbit of Uranus that culminated in the discovery of Pluto in 1930. Pluto's discoverer, Clyde Tombaugh, adds first-person credibility to *Out of the Darkness*.

Telescopes and other astronomical equipment can seem very mysterious to neophytes — therefore guides to equipment are very useful. J.B. Sidgwick's **Amateur Astronomer's Handbook** is available in two editions, one an inexpensive reprint of the 1971 edition* [Dover] and the other a considerably more expensive updated version [Enslow]. The book contains an extended discussion of astronomical equipment that ranges from theoretical optics through mountings to the physiology of vision.

Lagoon Nebula by Howard McCallon

Sam Brown's **All About Telescopes** [Edmund Scientific] is a superbly useful book. In a highly diagrammatic style, it provides a wealth of information on how telescopes work, how to design and assemble one out of components, and how to take astrophotographs; the approach is very practical.

Anyone interested in grinding his own optics ought to read Jean Texereau's **How to Build a Telescope** [Doubleday]. It is by far the best general book on making telescope mirrors and it covers the steps necessary to make an 8-inch f/6 mirror and assemble the telescope and mounting. The three volumes of **Amateur Telescope Making** [Scientific American] provide an enjoyable potpourri of telescope making. Compiled from articles that ran in *Scientific American* from the 1930s through the 1950s, the books cover all the fundamentals of constructing telescopes and interesting "peripherals," such as Schmidt cameras and unusual mountings. Although the material is somewhat dated, much is still useful. Volume one

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contains the basics, while volumes two and three delve more into the arcane topics.

Telescope Making* magazine is a quarterly periodical about building telescopes. It is indispensible if you're interested in what's happening in current telescope building. **How to Build a Dobsonian Telescope*** is a spin-off from it; it contains how-to articles on this new class of low-cost telescopes.

Those interested in astrophotography should examine Henry Paul's **Outer Space Photography** [Amphoto] and Newton and Margaret Mayall's **Skyshooting** [Dover]. Unfortunately, neither book is up-to-date, though they are adequate for the basics. Couple them with a back file of articles from ASTRONOMY's Photography in Astronomy department and you'll be on top of both the classic methods and the revolutionary changes in techniques and materials that have greatly altered astrophotography in the past few years.

space activist groups

Campaign for Space
300 M St. S.W., Suite 500
Washington, DC 20024

Citizens for Space
1900 Dufour, Suite 16
Redondo Beach, CA 90278

Delta Vee
3033 Moorpark Ave., Suite 27
San Jose', CA 95128

L-5 Society
1620 North Park
Tucson, AZ 85719

National Space Institute
Box 1420
Arlington, VA 22210

The Planetary Society
Box 3599
Pasadena, CA 91103

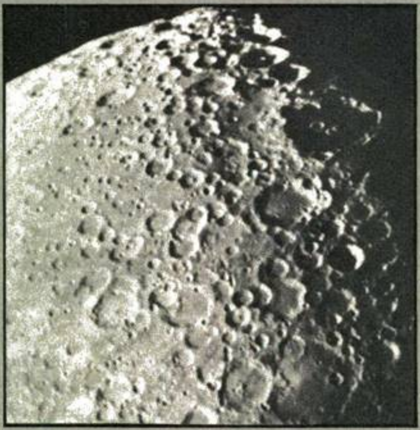
Space Studies Institute
Box 82
Princeton, NJ 08540

World Space Foundation
3202 Foothill Blvd.
Pasadena, CA 91107

A textbook is often the best source for answers to most general questions about astronomy. Dozens of them are on the market now with new editions appearing all the time, and most of them are fully indexed. Your best guide will be to look at the copyright date and use the most recent. Try for these in a college or university library.

One book often referred to for fundamental values is C. W. Allen's **Astrophysical Quantities** [Athlone Press]. Although it was published in 1973 and has gone increasingly out of date ever since, it tabulates more values of more numbers commonly used in astronomy and astrophysics than any other single source. This is another item to look for in a library.

The history of astronomy contains much material of human interest as well as being an absorbing story of intellectual development. Arthur Berry's **Short History of Astronomy** [Dover] covers the period from earliest times through the 19th century. Otto Struve and Velta Zeberg's **Astronomy of the 20th Century** starts in about 1880 and runs up to about 1960. Charles Whitney takes a different approach in his **Discovery of Our Galaxy**, since he concentrates on how astronomers of all periods have sought to find what the Milky Way really was, and how that search has led us to the expanding universe.



Lunar highlands by Jerry Spevak

The story of the telescope has been well documented in Henry King's **History of the Telescope** [Dover]. It is very detailed but stops its coverage at around 1950. Richard Learner's **Astronomy Through the Telescope*** [Van Nostrand Reinhold] is a colorful large-format book that recounts the telescope's history with less detail than King does, but brings the story up to the present.

In the last few years, several dictionaries of astronomy and space science have appeared. One of the most complete is Valerie Illingworth's **Dictionary of Astronomy*** [Facts on File]. Another good title is the **Dictionary of Astronomy, Space, and Atmospheric Phenomena** by David Tver [Van Nostrand Reinhold]. Since these are reference books commonly bought by libraries, consult their collections before you buy.

The widespread use of calculators and home computers has created a literature which caters to those who wish to do calculations that could formerly be performed only on large professional machines. Peter Duffett-Smith's **Practical Astronomy With Your Calculator** [Cambridge University Press] has routines for working out sidereal time, the phases of the Moon, and times of sunrise and set, to name a few.

Rummaging through heaps of print is only one way to learn about astronomy; another very pleasant method is to join a local astronomy club. Depending on its size, you'll find anywhere from five to 500 other members — nearly all of whom will be delighted to answer questions and help a beginner. Joining a club allows you to tap into an immense souce of information and experience which would take you several lifetimes to pick up on your own. To find a club in your city or county, ask at the local public library or newspapers and radio/TV stations. If this fails, send a self-addressed stamped envelope to Don Archer, Astronomical League Secretary, P.O. Box 3332, Des Moines, IA 50316, with a request for clubs in your area.

Besides local clubs, several national organizations promote amateur astronomical activities and foster public awareness of astronomy. These are listed in the box on page 56. "Space activist" groups, which organize public support for space exploration, are listed on this page.

The hobby of astronomy is far too rich to master all at once, and it would probably lose a lot of its appeal if anyone could "gobble it up" overnight. Although a newcomer might think of all these books as an insuperable hurdle to his enjoyment, this misses an important point. Astronomy is fun at *any* level of involvement, and the fact that there's a lot to it isn't really a drawback — after all, if you're given free run in a toyshop, who'd want it to be a small one? *Robert Burnham*

Ring Nebula by Jerry Spevak

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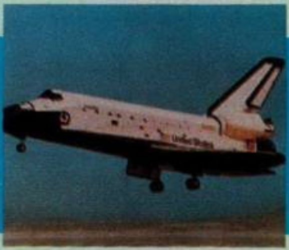

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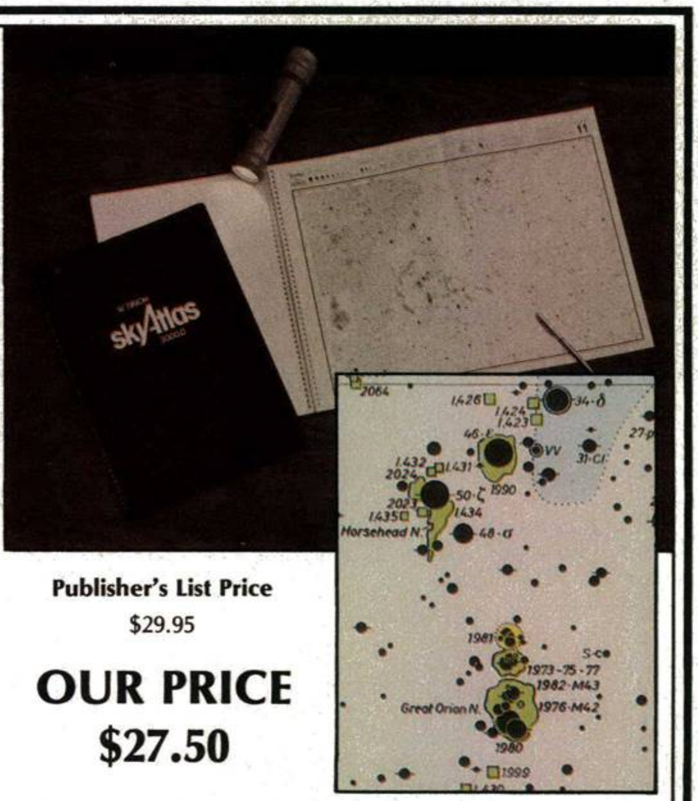

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When the Celestron 8 was first introduced, it caused more than a slight stir among serious amateur astronomers, astrophotographers and astronomy educators. Here, at last, was a large-aperture telescope designed for a modern age: it was really portable, easy-to-use and incredibly versatile. Today, the Celestron 8 is the world's best-selling 8-inch telescope.

Though it tips the scales at only 21 pounds and takes up less room than a suitcase, this 480X telescope more than delivers the optical performance so essential to the serious amateur or research scientist. And not only is the C8 the superior astronomical instrument its reputation suggests; remember also that every Celestron Schmidt-Cassegrain can be used as a powerful spotting scope for terrestrial observations and, when coupled to your camera, is a super telephoto lens (2000mm or 40X!).

With this instrument, the very textures of ordinary everyday objects stand out in bold relief, and their images are so brilliant — even in shadow — that high powers, completely beyond the capability of typical terrestrial spotting scopes, may be used routinely. Few people can look through a Celestron 8 for the first time and resist an exclamation of admiration for the optical quality of the instrument.

As an astronomical telescope the Celestron 8 frees you from the Earth's unyielding gravity so that you may freely roam the vast reaches of the solar system.

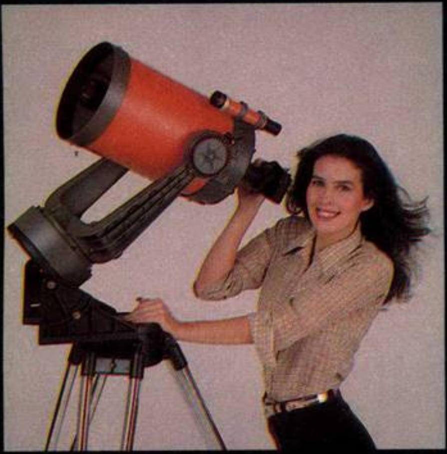
Well within the capability of the C8 are detailed observations of sunspot structure, the solar transits of Mercury or Venus, and a complete hierarchy of lunar craters.

Through the C8 under good seeing conditions the cloud belts of Jupiter appear discontinuous, composed of a multitude of streamers and festoons — and at this aperture the oranges, the reds and the browns of the Jovian clouds are revealed. Further, the moons of Jupiter now appear as disks and can be followed across the entire face of the planet.

With the C8, Saturn's rings are marvelously detailed. The main division (Cassini's division) is instantly obvious even at low power; the innermost (crepe) ring has a distinctly rosy appearance even against the background of space; and there is a noticeable brightening of inner Ring B, as well as a pronounced darkening of outer Ring A. Also visible through the C8 are at least two cloud belts and six of the planet's moons. Through the C8, even tiny Mars (with about half the diameter of Earth) is surprisingly detailed — especially during favorable oppositions. Then such surface features as Syrtis Major and Mare Erythraeum appear discontinuous, the clouds of the planet are visible and the facing polar cap as well as its melt band can be seen.

Under dark skies, the Celestron 8 brings its enormous light-gathering power and resolution to bear for the deep-sky observer. With more than 700 times the light-gathering power of the human eye, the C8 presents star clusters, nebulae and even galaxies in intricate detail. At this aperture, for example, the translucence that characterizes the planetary nebulae begins to emerge and globular clusters are resolved to the core.

Within visual reach of the Celestron 8 are such open clusters as the Pleiades or M35, such globular clusters as M13 or M3, such emission nebulae as the Orion Nebula or the Trifid Nebula, such planetary nebulae as the Dumbbell Nebula or the Ring Nebula, and such galaxies as the Whirlpool Galaxy or M33.



The C8 instrument on wedge and tripod.

For photography, convenient adaptors — available optionally — attach your 35mm SLR camera body or body-plus-lens to the Celestron 8 instantly, permitting telephotography, long-distance macrophotography, full-disk lunar or solar photography, close-up lunar or solar photography, planetary photography, basic deep-sky photography and constellation photography. Completely fills 35mm format.

The Celestron 8 is also capable of much, much more. In fact, with accessories, the C8 is capable of taking its owner to the very frontiers of contemporary deep-sky photography.

With the Celestron 8 as a central instrumental component, you will be able to duplicate on a smaller scale some of the most advanced photographic techniques practiced at the major observatories.

WHY THE CELESTRON 8?

The Celestron 8 is big where it's vital for high performance of its optical system, and small where it matters for convenience, weight and physical size. If you are serious about entering the hobby of astronomy or if you wish to graduate from a smaller telescope, the Celestron 8 can provide an answer to your needs, as it has for thousands of other individuals and schools. When you consider buying a telescope for a lifetime of observing and photography, remember that the C8 has the ability to grow with your interests and that only the Celestron 8 can provide:

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The base-price Celestron 8 is a complete working telescope and includes optical tube assembly, visual back, star diagonal, 25mm ocular (1¼" OD, 80X), 40mm ocular (1¼" OD, 50X), finderscope, fork mount, setting circles, manual slow motions, electric clock drive, clock drive cord, lens cap, carrying case and instruction manual.

BASIC C8 SPECIFICATIONS

Optical configuration	Schmidt-Cassegrain
Clear aperture	8 in. (200mm)
Effective focal length	80 in. (2000mm)
Photographic speed (focal ratio)	f/10
Highest useful visual magnification	480x
Near focus (approx.)	25 ft. (7.6m)
Resolution:	
Arc seconds (Dawes' limit)	0.6
Stellar magnitude limit	14
Image scale — degrees per inch	0.72
Film coverage (on 35mm format) at:	
30 feet	4 x 6 in. (0.1 x .15m)
100 feet	1.2 x 1.75 ft. (.36 x .53m)
1000 feet	1 x 17 ft. (.3 x 5.2m)
Secondary obstruction	12% (2¾ in. dia.)
Mounting (equatorial wedge optional)	fork type
Slow motion controls, both axes	manual
Electric clock drive — dual synchronous motors, solar rate	110v, 60Hz, 6 watts
Drive gear diameter	6 in. spur
Polar axis diameter	1⅜ in. tapered
Setting circles	Dec. 4 in., R.A. 8 in.
Optical tube dimensions	9 in. dia., 17 in. long
Optical tube weight	11¼ lbs. (5.1 Kg.)
Telescope size, swung down	9 x 13 x 24 in. (23 x 33 x 61 cm)
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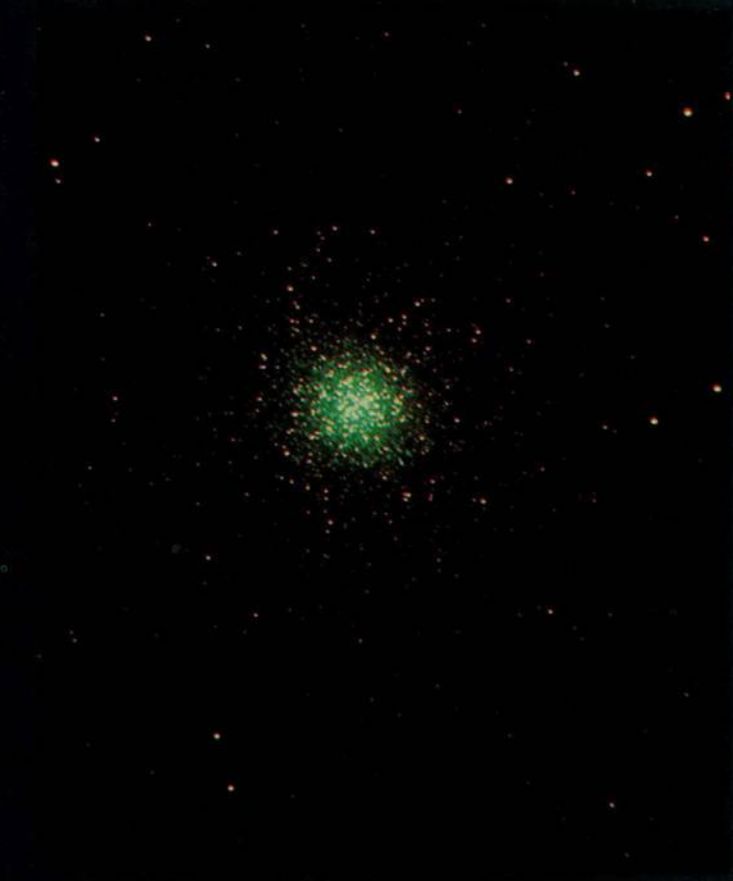
Celestron 8 Astrophotographs

Trifid Nebula M20



Globular Cluster M13

Eagle Nebula M16

Lunar Eclipse

Saturn

Jupiter

Spiral Galaxy M51

ASTRONEWS

FY'83 Planetary Exploration Budget Cut

A White House insider passed this tidbit on to a reporter last summer: At a review of NASA's 1983 budget, David Stockman, the President's budget director, declared that planetary exploration is a waste of money. He vowed to end it within three years.

This sounded like other stories running through the planetary science community, though many thought they were just rumors. *Publicly* the President's people said only that the exploration had grown too expensive and needed trimming.

The administration's 1983 NASA budget proposal still leaves White House intentions unclear. It requests money for the expensive Voyager and Galileo missions, yet hacks at inexpensive items that give the program strength and breadth. Reagan's staff wants a change — but to what degree?

The Office of Management and Budget (OMB) had decided to kill the Galileo Jupiter orbiter and atmospheric probe — the only new mission planned for this decade. NASA officials appealed directly to the White House and saved the project. Galileo's reprieve wasn't total, though.

A space shuttle will carry the spacecraft and probe into Earth orbit. From there, an upper stage will propel them onward. The agency lost the money for the Centaur booster it wanted to use. Switching to a less powerful booster will mean a two year longer flight to Jupiter, an extra $150 million in expenses, and 50% fewer flybys past the planet's moons.

Still, Galileo did better than VOIR. The Carter administration had approved this Venus mapper in its final budget. The Reagan administration then "delayed" the mission.

With Galileo approaching its 1985 launch, and VOIR gone, NASA faces the prospect of losing the engineers and other specialists who put planetary missions together. To prevent this, NASA must soon receive funding for a new mission.

There will be money to operate Voyager I as it leaves the solar system and Voyager 2 as it heads for Uranus. Preparations will begin for Galileo's mission to Jupiter. And the Viking lander will continue transmitting its weekly weather report and picture from Mars.

However, no funds are available to operate Pioneers 10 and 11 or Pioneer Venus Orbiter. Next January, these craft will receive commands to turn themselves off; they can't be turned on again. All three could have continued their studies for another decade.

At 28 A.U. from the Sun, Pioneer 10 is the most remote of mankind's probes and the distance increases by 2.39 A.U. a year as it flees the solar system. Pioneer 11 follows behind at 11 A.U. These tiny probes were the first to explore Jupiter and Saturn. Now they investigate the Sun's magnetic field and the plasmas coursing through it.

The *Pioneer* Venus orbiter has studied Venus' ionosphere since December 1978, watched its weather, and mapped most of its surface. Planetary scientists had planned to allow the Sun's gravity to reshape the craft's orbit so that they could pursue new studies.

For the first few years, engineers kept the orbit's closest approach to the planet, the periapsis, just above the atmosphere. Now they're letting the periapsis slowly drift outward. The increased distance would have permitted the spacecraft to fully explore several key regions of the ionosphere.

After 1986, the periapsis will begin drifting back down. In 1992, it again will be just outside the atmosphere. This time, though, it will lie over the southern hemisphere instead of the northern hemisphere. The orbiter could have extended its map from 64°S to 73°S. The current map hints at a highland area in this region.

Pioneer Venus could have also studied Halley's comet. When the comet makes its closest approach to the Sun in 1985, just 30 million kilometers will separate it from Venus. The Earth will lie on the other side of the Sun. Pioneer Venus could have made detailed ultraviolet and solar wind measurements during this crucial time in the comet's passage through the inner solar system.

"The administration wants us to find cheaper ways to explore the solar system," says Larry Colin, Pioneer Venus project scientist. "Yet it decides to throw away the three Pioneers, worth $500-600 million, to save the $7 million a year needed to operate them and analyze their data."

Perkin-Elmer Photo

The 94-inch mirror for NASA's Space Telescope, set for launch in 1985, was recently coated with its special reflective surface.

However, the cuts in research and analysis will hurt the scientific study of the planets most. Losing VOIR and the Pioneers mean their studies must await another time. Losing research money means cutting into the heart of planetary science. The new budget slices deep.

Research and analysis covers everything that's not the development or operation of a mission. It includes, for example, the engineering studies of future Mars orbiters and preparation for the Halley watch that will coordinate observations of the comet. It also includes the salary, the overhead, and the computer time of a scientist examining craters on Venus.

The administration wants a 29% cut here. Dividing the remainder falls upon the director of NASA's Earth Planetary Exploration Division, Jess Moore. "Preserving people," he says, "is my top priority. Without the scientists, it doesn't matter whether we have missions or not. We couldn't analyze their data."

Moore has decided that the lunar curatorial center will no longer distribute the samples collected by the Apollo astronauts. The Infrared Telescope Facility in Hawaii, which is the best infrared observatory in the world, will close. The program saves $3 million this way, enough to retain 30 researchers Moore would otherwise have to cut. Still, some 150 of the 650 scientists supported by NASA out of this fund will find themselves without money.

"I really fear that the cohesive nature of planetary science will be lost," says Clark Chapman, chairman-elect of the American Astronomical Society's Division for Planetary Science. "Whole areas of research may have no one working on them."

What do these cuts say about the future? Chapman thinks they confirm the rumors. "OMB clearly intends to get out of planetary exploration. Last fall, it asked NASA how fast it could do so. The answer was it could kill Galileo and mission operations immediately, but phasing out the

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research would take three years."

According to Chapman's sources, a coalition of southern California politicians, Galileo was saved so that JPL, which is building the craft, would stay alive until it could become a defense center. The future of planetary exploration had little to do with the decision. "Except for Galileo," continues Chapman, "OMB hasn't deviated at all. The cuts in mission operations and research are part of the phase out. Galileo may reach Jupiter with almost no one to study its findings."

Andrew Stofan, acting head of space science during the drafting of the budget, sees things differently. "The White House doesn't plan to end planetary exploration, but it feels that this field has had its heyday and the emphasis should shift to astronomy and astrophysics. The days of the $700-million-plus missions are over. Lower-cost missions like the Pioneers are looked at more favorably." Stofan believes the rumors came from budget exercises in which OMB looked at the effect of ending any of several NASA programs. It decided to continue all of them.

If the administration asks for further large cuts in the 1984 budget, then Chapman's hypothesis will be borne out. If the funding level stays more or less the same, then Stofan may be right.

If the original policy was to end the planetary program, it may have changed. By agreeing to continue with Galileo, OMB almost guarantees that some kind of planetary program will continue for the next few years.

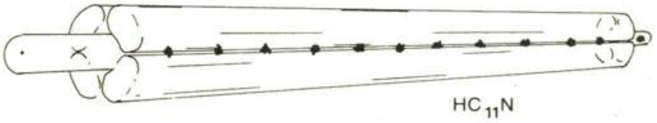
For the scientists who remain, a tremendous amount of data from previous missions waits for a thorough examination. New data will come in from the Soviet Venera landers in 1984, the Soviet, Japanese, and European Halley flybys in 1986, and Voyager Uranus encounter also in 1986 — plus continuing ground-based observations. The ultimate fate of planetary exploration will be decided in the mid-1980s when NASA requests new missions.

In the meantime, Chapman expects Congress to increase planetary exploration's 1983 funding somewhat. NASA also could shift some money to planetary sciences from other programs. Even so, America's planetary exploration program will be smaller. *Van Kane*

Huge New Space Molecule Found

A prediction by astronomers has led to the discovery of a new molecule in space — the largest and most complex ever observed. Cyano-deca-pentayne, $HC_{11}N$, has been found in a shell of dust and gas enshrouding the star CW Leonis. (See "Molecules Between the Stars," ASTRONOMY, March, 1982.)

CW Leonis is a cool carbon star 600 light-years from Earth and astronomers believe it is undergoing extensive mass loss while producing a dense circumstellar envelope rich in neutral molecules and free radicals.



$HC_{11}N$

For the past 20 years astronomers have found more than 50 types of molecules in interstellar space by studying their radiations in the radio spectrum. These molecules only occur in regions of dense dust and gas, because the high density of atoms allows the formation of molecules. The dust screen prevents the molecules from being torn apart by ultraviolet light from nearby stars.

Using the Algonquin radio telescope in Canada and the Haystack telescope in the United States, astronomers found HC_9N and some puzzling emissions that they thought could be evidence for the existence of a larger molecule. Although $HC_{11}N$ does not exist on Earth, the astronomers were able to deduce its spectral characteristics. That gave them something to look for in their data.

This is the largest molecule found in space or in the atmospheres of any of the planets. It contains 13 atoms, has a molecular weight of 147, and is 1.5 nanometers long.

Venus Conference Reports New Discoveries

Dramatic new finds about Venus were reported at the NASA-University of Arizona sponsored first International Conference on the Venus environment, held in Palo Alto, California, Nov. 2-6, 1981.

These include: evidence for two major, currently active volcanic areas on the planet; the probability that these areas are the principal vents for the planet's internal heat; quantified findings that Venus has a thicker crust than Earth and is a "one plate" planet with little plate tectonics; and complete, self-consistent models of Venus' cloud system and greenhouse effect. Considerable progress has also been made in understanding overall atmospheric circulation (with implications for Earth); and there is strong new evidence for former venusian oceans on the scale of the Earth's oceans.

Several hundred scientists from the U.S. and other countries attended the recent Venus conference. Much of the new information comes from data returned by the six Pioneer spacecraft and their 30 experiments.

New Venus discoveries included:

1) Apparently there are two major volcanic regions on Venus: Beta Regio and the "Scorpion Tail" of Aphrodite Terra, the largest continent-like upland region on the planet. There is evidence for continuous and current volcanic activity at both places.

2) Detailed analysis of Venus' global topography and detailed comparisons with global crustal-density show that Venus apparently has a thicker crust than Earth and is a "one plate planet." Substantial evidence indicates that its crust is not broken into many continent-bearing plates, floating on the liquid interior, as the Earth's crust is.

3) Because of its thick, planet-wrapping crust, most of Venus' interior heat appears to come out in its two volcanic regions. Earth vents its heat at many points, especially at the constantly-

YOU LOST SOMETHIN' DOWN THAT BIG PIPE, BOY? Gary Hertzler

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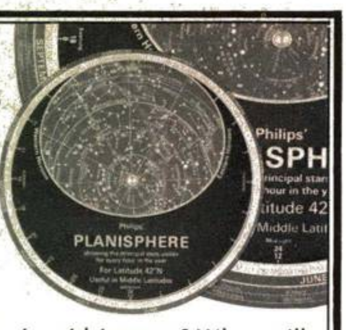

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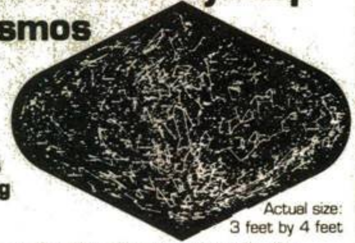

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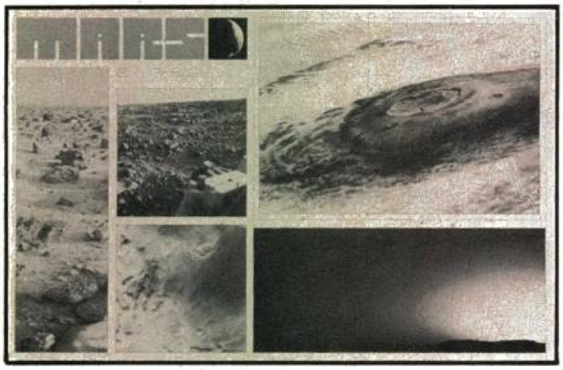

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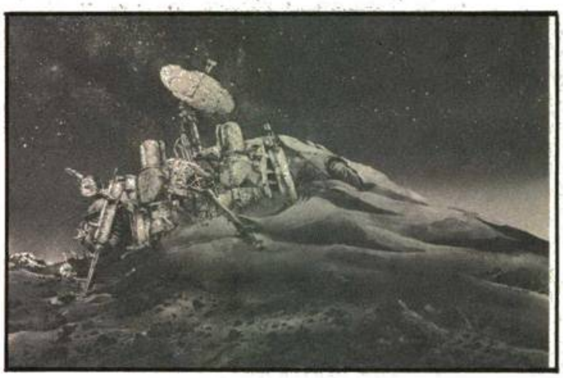
15 miles high and 400 miles wide, Olympus Mons dominates this dramatic poster of images returned by the Viking spacecraft. (M)



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expanding mid-ocean ridges. Concentration of Venus' lightning over just two volcanic regions suggests fairly frequent current volcanic activity in both places.

4) Beta Regio, a region larger than the terrestrial Hawaii-Midway island chain, appears to be a huge double-shield volcanic construct, and is apparently the most active region on the planet. This is shown by variations in crustal density, apparent old lava flows, and the region's 20,000 foot height and huge size. Beta is believed to sit over a powerful, upflowing convective plume, deep in Venus' interior.

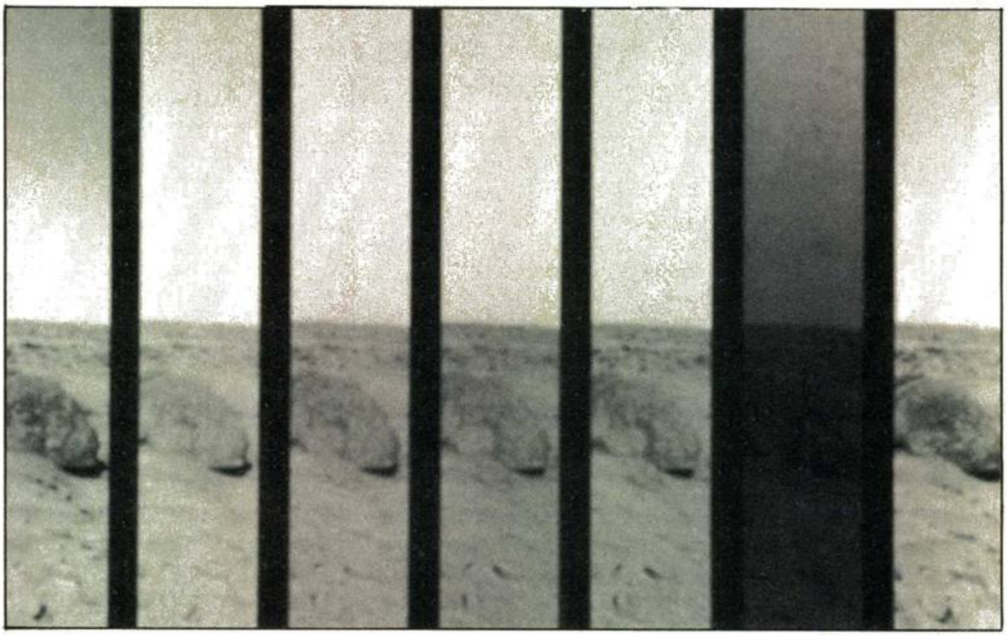
5) Venus' clouds are "upside down." There's a smog layer on top, 15 km deep, and Earth-like condensation clouds (made of sulfuric acid droplets) below 57 km, extending down to 48 km. These condensation clouds are patchy and vary in density. They drizzle but seldom rain very hard and in general are only ten percent as thick as comparable terrestrial clouds. Scientists also have now charted and quantified the basic cycle of chemical reactions in the clouds.

6) Unlike Earth, which absorbs most solar heat on its surface, Venus absorbs most solar heat in its clouds. In the cloud layer is a single convective circulation cell which carries heat from equator to pole. Earth has three major circulation cells transporting heat between equator and poles.

7) Venus appears to have had an ocean and lost it to space. During the solar system's early history (when, scientists believe, the Sun was 30 percent less hot), Venus' atmosphere and environment could have been Earth-like. With water abundant, the planet may perhaps have sustained life during the early years of the solar system's history. When the runaway greenhouse effect began, it wiped out most existing phenomena on the planet and replaced them with today's furnace-like environment.

Changing Images From Mars

Seven new images from Viking I show Mars before, during and after a dust storm. The Lander's camera captured the storm in progress (sixth frame) on June 14, 1981. Prior to and after that frame, the sky and surface are brighter. are brighter.



Viking I/NASA Photo

The photos, processed in JPL's Image Processing Laboratory, were taken over two-thirds of a Mars year — one-and-a-half Earth years. The change in apparent brightness of the large boulder named "Big Joe" is due to seasonal changes in the Sun angle. Now that they have studied the planet for one Mars year, scientists can separate brightness differences caused by the Sun from those caused by storms.

Images taken over a long period of time will allow scientists to observe year-to-year changes around the Lander that can reveal the geological processes acting to shape the surface of Mars. The Viking 1 Lander is programmed to return imaging, meteorological and radio science data until 1994.

Japanese Sponsor Shuttle Experiment

The *Asahi Shimbun*, one of Japan's major daily newspapers, has signed an agreement with NASA to fly a small "Get Away Special" experiment aboard an orbiting Space Shuttle, possibly in late 1982. The experiment will use the weightless environment of space to make pure artificial snow crystals directly from a gaseous substance.

The experiment was suggested by two Japanese high school students and was chosen from some 17,000 suggestions submitted by *Asahi Shimbun* readers. It is expected to contribute significantly to present knowledge of crystallography, especially the crystal growth of semiconductors or other materials from a vapor source.

The first artificial snow-crystal experiments were made by a Japanese physicist, the late Dr. Ukichiro Nakaya, in 1936.

Since then, a variety of follow-up artificial snow experiments have been carried out by Japanese scientists. This experiment will be the first to make artificial snow in a weightless environment.

Get Away Specials are privately funded experimental payloads flown by NASA aboard the Space Shuttle on a first come, first served basis. To date, NASA has accepted 321 Get Away Specials to be flown on a space-available basis with major scheduled payloads beginning with the fifth Space Shuttle flight in 1982.

The Case of the Missing Mass

Researchers studying long-lived subatomic particles inadvertently have produced an indirect test for neutrino mass.

Scientists now think neutrinos lack both mass and electrial charge. But some theorists suggest that if neutrinos have mass, then one of the great cosmological questions might be answered: Is the universe open or closed?

Physicists now suggest that the universe is "open," since they haven't found enough matter for gravitational attraction to pull together everything that was thrown out as a result of the "Big Bang."

However, if neutrinos have mass, then this could account for the missing mass needed to "close" the universe. (See "The Invisible Universe," ASTRONOMY, May 1981.)

Bill Reay, physics professor at Ohio State University and spokesman for a collaborative project at the Fermi National Accelerator Laboratory near Chicago, says that the researchers were looking for evidence that one type of neutrino was able to change into another type.

To do this, Reay says, at least one type of neutrino has to possess mass. The particle beam used at Fermilab contains muon neutrinos which change into muons when they interact with nuclear matter.

"If the muon neutrinos spontaneously changed into tau neutrinos during the experiment, then we have seen the making of tau particles instead of muons," Reay says.

Measurements indicate the tau particles live a billion times longer than typical subatomic particles. Even so, in human terms, tau particles *still* have quite a short lifetime.

The researchers wanted to find

An open letter to Meade and Celestron owners from the President of Meade Instruments Corporation

Recently, advertising by Celestron International has appeared in this magazine which we believe has led to confusion and dismay among Meade and Celestron owners. While it is not normally the Meade way to answer such advertisements, we feel an obligation to the thousands of Meade Schmidt-Cassegrain owners to set the record straight.

1. **The Advantage of an Oversize Primary Mirror in a Schmidt-Cassegrain (SC) Telescope.** Celestron states that an 8″ primary mirror oversized by only .008″ in radius is sufficient to catch outer light rays deflected through the SC corrector plate on their way to the primary mirror. This analysis is correct **for light parallel to the telescope's optical axis,** i.e., for light imaged precisely in the center of the telescopic field. For light rays imaged ½° off-axis, i.e., rays imaged near the edge of the field of view, a simple mathematical analysis* proves unequivocally that, apart from baffling, **the primary mirror in an 8″ SC telescope must be 8.218″ diameter, in order for these off-axis rays to be imaged fully.** Celestron ignores these off-axis rays completely in their oversize-primary analysis.

   Fig. 1 demonstrates the above statement: The on-axis ray (1), which is imaged at the center of an SC telescope's field of view, is deflected .008″ by the corrector plate, and only a slightly larger primary mirror of 8.016″ diameter is indeed required to image this ray at the focal plane. But ray (2), which is ½° off-axis, and which is imaged near the edge of the telescopic field, requires an 8.218″-diameter primary in order to be imaged at all. The Celestron C-8, with its 8.060″ primary mirror, does not image this ray, while the Meade 2080, with its 8.250″ primary, does. The result is significantly brighter (about 10% brighter) off-center images in the 2080 than in the C-8.

2. **Image Brightness.** Celestron's own graph, reproduced here as Fig. 2, attests to the superior image brightness in the Meade 2080, as compared to the Celestron C-8 and Dynamax-8 telescopes. Note from Fig. 2 that the C-8's image brightness falls off rapidly for light rays more than 0.2° away from the center of the telescopic field. In fact, surprisingly, Celestron admits in this graph that the **Meade 2080's image brightness is uniformly greater than the C-8, for star images located between 0.2° and 0.6°** from the center of the field, **an area comprising more than 65% of the total telescopic field.** Over the other 35% of the field, image brightness is the same in both telescopes. (For reference, the actual radius of the field of view at the Cassegrain focus in both the 2080 and C-8 is about 0.7°.) In fact, because of its smaller primary and secondary mirrors, and because of its light baffle design (see below), **the C-8 is operating as a 7.59″-aperture telescope of 2080-type design, for a star located 0.3° off-axis** (i.e. about half-way from center-to-edge of the field). Equivalently, **it would require a Schmidt-Cassegrain telescope of 8.39″-aperture of the C-8 design to duplicate the off-axis image brightness of the Meade 2080.** The C-8 **with** high transmission coatings does not yield off-center images as bright as the Meade 2080 **without** coatings.

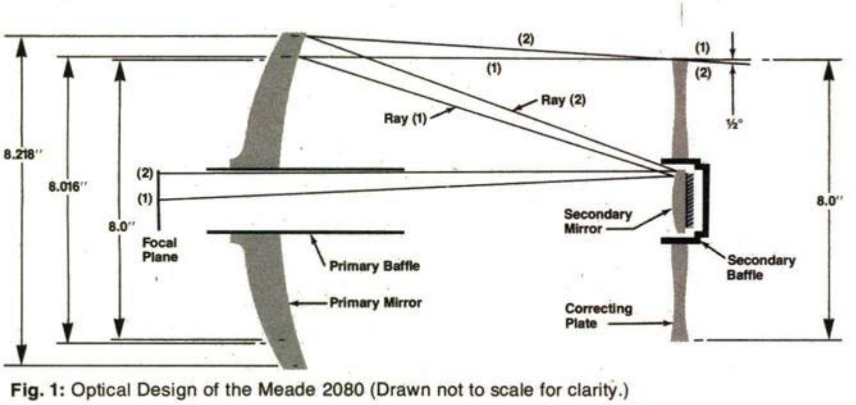


Fig. 1: Optical Design of the Meade 2080 (Drawn not to scale for clarity.)

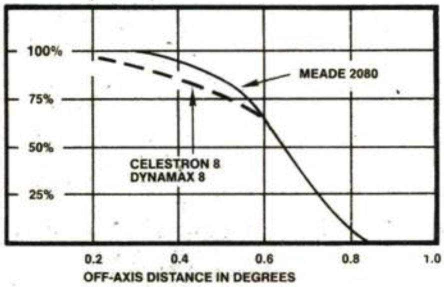


Fig. 2: Off-Axis Field Illumination. The vertical axis represents image brightness, expressed as % of maximum illumination. This graph, produced by Celestron, confirms the Meade 2080's superior field illumination over both the Celestron C-8 and Dynamax-8.

3. **Light Baffles.** An oversize primary in an SC telescope is of no advantage, however, if the internal light baffles are not designed to take advantage of this fact. Simply increasing the primary mirror diameter of the C-8, for example, will result only in marginally increased image brightness, because the C-8's light baffles preclude most of the additional light ever reaching the focal plane. In the Meade 2080 the primary and secondary mirror diameters, and the baffle dimensions, were computer optimized **as a system** to produce the additional image brightness confirmed by Celestron's own tests.

4. **The Absence of Stray Light in 35mm Photos Through the Meade 2080.** Using an oversize-format camera for which the 2080 was not designed and, we believe, by significantly overexposing the photo, Celestron in their ad was able to show a halo outside the 2080's field of view. This halo is not in any way the result of the opaquing of the baffle tubes. In fact, it is precisely because the 2080 was designed to optimize 35mm film illumination that unshielded light reaches only outside the field of view, as it should. Halos are never present in 35mm photos through the 2080, and images, with proper exposure times, are of extremely high contrast.

The Celestron C-8 was designed in the 1960's, and has remained essentially unchanged in optical design since that time. It remains a fine example of the technology of the 1960's. The Meade 2080 incorporates recent computer optimization techniques which, we feel, fully utilize modern design approaches now available.

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ASTRO NEWS

evidence of these longer tau lifetimes. They hoped that a search of photographic emulsion used to record these nuclear events occasionally might show the formation of tau particles rather than muons, he says.

"No taus were found," Reay explains, "which indicates that muon neutrinos can't change into tau neutrinos. We therefore found no evidence that either of these types have mass."

The lack of evidence for neutrino mass came as a byproduct of a series of experiments that produced different charmed particles by neutrino interactions.

"In addition to using emulsions, a complex electronic detector was used during the neutrino exposure to pinpoint the exact interactions and get information on the products made by charmed particle decay," he says.

The researchers found evidence proving that charmed particles do indeed live a long time. Unexpectedly, they found that various species of charmed particles had differing lifetimes.

The experiments also established the existence of the charmed F-meson, a predicted particle, and researchers found a previously unexpected long-lived neutral charmed baryon. Reay is quick to point out that, so far, they found only one event of this type.

Reay and his colleagues also found some evidence that the D-zero charmed meson may decay at two entirely different rates. If, when the analysis of the experiments is complete next year, the records show that this meson does have two distinct lifetimes, "it would be quite surprising and could offer a new direction for future physics theories," Reay says.

Was Comet Once Jovian Satellite?

Astronomers have long thought the small outer moons of Jupiter are probably captured asteroids or comets. In 1979 Brian Marsden of the Harvard-Smithsonian Center for Astrophysics published the most likely orbit for the periodic comet, P/Gehrels 3. It was based on twenty observations made between the comet's discovery date — October 1975 — and March 1977. The orbit indicated the comet was gravitationally bound to Jupiter from December 1966 to July 1974. In addition, the orbit allowed it to approach Jupiter twice: once in August 1970 — to within 209,000 kilometers — and again in March 1973 — to within 6 million kilometers.

Writing in a recent issue of *Astronomy and Astrophysics*, two Swedish astronomers — H. Rickman and A.M. Malmort — report that Comet P/Gehrels 3 was indeed temporarily a jovian satellite — which they defined as one which is gravitationally bound to Jupiter for at least several years and which completes at least one revolution about Jupiter.

Comet Encke/Lick Observatory Photo

The two astronomers ran a computer program which matched the observed orbit of the comet during the time of observations and then traced the orbit back in time, taking into account the gravitational influences of the Sun, Jupiter, and the comet. They ignored the gravitational influences of Jupiter's four Galilean satellites, the most important differences between their model and the real situation. However, the scientists expect the resulting errors will be small.

They took an orbit resembling Marsden's as a "central orbit" in which they varied slightly such orbital elements as the eccentricity, the inclination, and the semi-major axis. A total of 230 different orbits resulted, and all indicated recent gravitational binding to Jupiter for a period of at least several years. Most gave the comet at least one revolution around Jupiter. Those orbits which did not allow a revolution were in general rather different from Marsden's orbit.

The scientists cite two reasons to believe the true orbit of the comet is close to that computed by Marsden. First, the orbit is based on a rather extended series of observations. Second, nongravitational forces are likely to be very weak.

They conclude, "This shows definitely that Comet P/Gehrels 3 was indeed a temporary jovian satellite shortly preceding its discovery." *Ken Croswell*

A Private Shuttle?

In the early 1970s, Klaus Heiss helped prepare studies to show the need for a space shuttle. In the mid-1970s, he helped the space agency decide what prices to charge for launching payloads with it. Now he wants to buy one.

Heiss' firm — The Space Transportation Co. Inc., a subsidiary of the investment firm Wm. Sword & Co., Inc. — on February 8 gave NASA a proposal that may mark a turning point in the space age. For the first time, a private company wants a part in the shuttle program as a partner to the government — not as a contractor. STC wants to finance a fifth orbiter for the government to use free of charge. In return, STC wants the exclusive right to sell the shuttle's payload space to private companies and foreign governments.

The communications satellite industry has grown enormously; it now builds more satellites each year than NASA. And the problems in developing the shuttle have meant that the space agency can't promise to launch a satellite on the shuttle at all — much less promise a firm date. Businessmen don't like to operate that way, so this opens up a market to operators of a fifth shuttle, or any company that can launch a satellite. At the moment, Arianespace, a predominately French-owned company that markets the European Ariane booster, has successfully stolen several of NASA's customers even though the shuttle is cheaper.

"Ariane," says Heiss, "isn't any better than the Delta boosters the U.S. has had for years. Arianespace wants to make money so it undersells the Delta and offers attractive terms. The U.S. government can't operate like this. It can't even take a potential customer to lunch. Effectively, all it can do to sell the shuttle is say, 'Here it is. Use it if you can.'

"If NASA accepts our proposal, we'll have $1 billion sunk into an orbiter. Our profit will depend on how many payloads we get to fill its cargo bay. We'll have to meet our customers needs."

STC owes its birth to government cutbacks in the shuttle program. Study after study had shown that the country needs at least five shuttles: two for military payloads, two for other government payloads, and one for commercial and foreign payloads. A fifth craft not only supplies needed launch capacity, it also ensures continued service if one shuttle is damaged or destroyed. Even so, the Carter administration canceled the fifth orbiter in 1978.

"I told the people at the Office of Management and Budget that five was the minimum," recounts Heiss. "'If the need is so great,' they asked me, 'why aren't companies buying shuttles?' So I asked them if they'd agree to a private shuttle purchase. They said yes."

William Sword's investment bank organized STC the following year with Heiss as president. Five of the eight board members are investment bankers with experience in financing billion-dollar-plus ventures. They aren't starry-eyed about space — they want to make money.

After three years of study, STC believes it has an arrangement that will make a profit and benefit the nation at the same time. It boils down to three key points:

— STC finances the fifth orbiter. Once it's built (1986 is the earliest), the government uses it as a normal part of the fleet.

— In return for its investment, STC receives marketing rights for the entire fleet. Companies and foreign governments will pay STC for launching their satellites. STC's profit is the difference between what it receives and what it pays the government for the launch.

— Unless the government insists on heavily regulating STC's activities, the company won't ask the taxpayers to guarantee its

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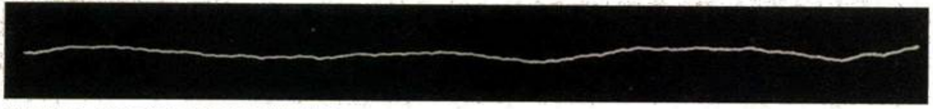

FIGURE 1: C8-S/N813888 DRIVE TEST

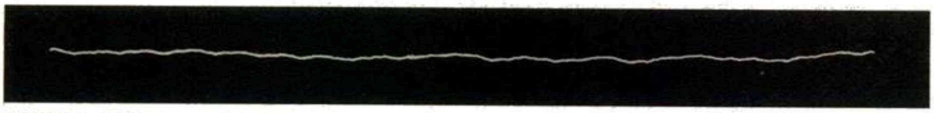

FIGURE 2: C8-S/N811280 DRIVE TEST

Figures 1 and 2 above are average results of drive tests of Celestron 8 telescopes. They were made by deliberately misaligning the polar axis of the telescope by a fixed offset from the celestial pole. Specifically, the setting circles were used to cause the polar axis to point 10 degrees west of the celestial pole. Then, with the telescope stopped down to about f/50, a star of fourth or fifth magnitude located near the celestial equator and near the meridian was photographed for 15 minutes. The resulting star trails shown above can be analyzed for magnitude and rate of any tracking errors of the drive system. By inspecting these figures and figure 3, it can be easily shown that any drive system errors can be overcome during deep-sky photography by using a drive corrector.

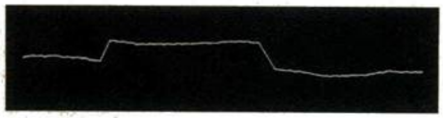

FIGURE 3

Figure 3. — Star trails photographed using the same procedure as above, but using a drive corrector as the 60 hz. source for a Celestron 8. At 3 minutes into the test, the slow button was depressed and held for 12 seconds. Then, at 8 minutes into the test, the fast button was depressed and held for 12 seconds. Note that the tracking error introduced by the drive corrector buttons exceed the errors in the drive itself by at least a factor of two. We are simply demonstrating in this photograph that a standard drive corrector has more than enough overriding capacity to offset any clock drive error that could affect a long exposure astrophotograph.

A telescope clock drive is provided so that the instrument will automatically rotate about its polar axis to counter the rotation of the Earth on its axis. This causes a star field to remain fixed in the field of view of the instrument. Consider that if you were viewing Jupiter at 450 power without a clock drive; the image would traverse from the center to the edge of the field of the ocular in only 10 seconds of time.

How accurate must the clock drive system of a telescope be? How do you evaluate the accuracy of such a system? Certainly if the image appears stationary in a high power ocular, the drive system is adequate for visual work. On the other hand, if you are using the telescope to take guided deep-sky photographs, and if you can keep a guide star centered on the cross hairs of a high power guiding eyepiece, the drive system is adequate for this purpose.

The photographs here document an evaluation of the clock drive accuracy of the average Celestron 8 Schmidt-Cassegrain telescope. The procedure used was as follows: The declination setting circle was used to set the polar axis of the telescope under test so that it pointed 10 degrees west of the celestial pole. A 4th or 5th magnitude star near the celestial equator and the meridian was photographed for 15 minutes. The resulting trail on the film is a north-south line about one inch long (at the 80-inch e.f.l. of the Celestron 8). Variation from a straight line of this star trail can be evaluated for change in clock drive speed and duration of these changes.

As you can see, these telescopes each exhibit some clock drive errors as any commercial telescope will. For deep-sky astrophotography in any commercial telescope, you must use a drive corrector to control clock drive error. Celestron does not wish to imply that deep-sky astrophotography is an effortless task; it is a learned skill, an art as much as a process; the more you practice, the better your results.

Without evaluating the underlying facts, an astrophotographer might automatically specify a worm gear for the clock drive of a telescope. This as opposed to a dual-spur gear drive such as used in the Celestron 8. If a worm-gear drive is to present any improvement over the spur gear drive, the worm wheel itself should be fully generated by multiple pass hobbing, and the worm must be precision lapped. However, this is just the beginning. It is not the run out of the worm in the case of the worm drive or the one-hour rotation period of the pinion gear of the Celestron 8 drive which could introduce drive fluctuations which might be difficult to guide out with the drive corrector. It is the higher speed reduction gears in the drive motors, which if other than perfect, create small but rapid variations in the drive speed. If inexpensive timing motors are used in conjunction with a worm drive, these high speed variations will be introduced by the spur gears in its reduction train. The Celestron 8 and competitive units use timing motors with spur-gear speed reducers. In the case of the Celestron 8, however, two motors are used which drive at opposite diameters to the main drive gear. This, in effect, loads one motor against the other to dampen high-speed gear variations.

The adequacy of the drive system of the Celestron 8 is attested to by the multitude of photographs that have been submitted by Celestron owners and published in the various journals. Of course, you can purchase a separate worm drive system for the Celestron 8. We consider that only those which cost several hundred or even thousands of dollars offer sufficient precision to yield any improvement over the standard Celestron 8 drive.

In our photographic analysis, Celestron has attempted to provide a definite demonstration that intelligent engineering and responsible manufacturing can produce an instrument, the Celestron 8, that is superior to competitive instruments.

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ASTRO NEWS

profits. It does want its client's payloads to have equal scheduling priority with NASA's payloads.

NASA won't comment on the proposal. But the idea interests the agency. After meeting with STC personnel several times, NASA's management encouraged Heiss to submit a formal proposal.

Heiss's proposal contains information the government must have before it can decide on questions such as these: Would the financial arrangement be such that the government would do better to pay for the fifth orbiter on its own? Can the government operate the fleet with a private company selling part of the cargo space? Would the taxpayers benefit? Would shuttle users benefit? Both sides expect they'll have to dicker over the details.

The decision must come soon. Rockwell International, prime contractor for the orbiter, and its subcontractors will begin shutting down their production lines within a few months unless an order for a fifth shuttle comes in. Re-opening the lines after they've been closed adds between one-half to one billion dollars to the cost of the orbiter.

Reagan's desire to turn government functions over to free enterprise improves STC's chances of getting a shuttle. His administration has balked twice at paying for an additional orbiter with taxpayers' money. The President's Office of Science and Technology Policy has encouraged STC to push forward.

"As the use of space matures, we expect to see more and more private involvement," says NASA spokesman Bill O'Donnell. "The government developed communications satellites and then turned the technology over to the private sector. Space transportation now may have reached the point where free enterprise will have a role."

Heiss and his backers feel it's ready. Launching communication satellites alone, they believe, will return a reasonable profit. The growing interest in Earth resource satellites and space manufacturing can provide even more business.

If that happens, STC will continue investing in space transportation. It would buy as many additional shuttles as it can fill with payloads. Eventually the company might invest in manufacturing the shuttle's external fuel tank, its upper stages, or possibly even in a space station. *Van Kane*

ASTRO CALENDAR

May 1.	**Astronomy Day, 1982.** Any group or institution planning an Astronomy Day program. Contact: Astronomy Day Listings, A.S.P., 1290 24th Avenue, San Francisco, CA 94122.
May 1.	**Telescope User's Clinic.** Contact: Western Observatorium, 13215 E. Penn St., Suite 411, Whittier, CA 90602.
May 1.	**International Workshop on Cometary Astronomy.** Bryant College, Smithfield, Rhode Island. Contact: Richard F. Lynch, 12 Greenbrier Rd., Greenville, RI 02828.
May 9-14.	**The New Astronomies.** Tucson, Arizona. Contact: Selected Studies, A&I 1190A, Smithsonian Institution, Washington, DC 20560.
May 10-13.	**Symposium on Photoelectric Photometry with Small Telescopes.** Auckland, New Zealand. Contact: W.H. Allen, P.O. Box 5526, Moray Place, Dunedin, New Zealand.
May 18-22.	**Saturn Conference** (professional meeting). Tucson, Arizona. Contact: M.S. Shapley, University of Arizona, Lunar and Planetary Laboratory, Tucson, AZ 85721.
May 22.	**36th Annual Convention of the Astronomical League's North Central Region.** Carroll College, Waukesha, Wisconsin. Contact: Milwaukee Astronomical Society, William G. Konig, P.O. Box 275, Mequon, Wisconsin 53092.
May 26-28.	**Big Bear IAPPP Symposium.** Camp Oaks, Big Bear, California, just prior to Riverside TMC. Contact J.L. Hopkins, 7812 W. Clayton Dr., Phoenix, AZ 85033.
May 26-30.	**Amateur Astronomy and Telescope Making Conference** sponsored by the Astronomical League's S.W. Region. Fort Davis, Texas. Contact: George D. Ellis, 7117 Misty Meadows Dr. S., Fort Worth, TX 76133.
May 28-31.	**Riverside Telescope Maker's Conference.** Big Bear, California. Contact: Cliff Holmes, 8642 Wells Avenue, Riverside, CA 92505.
June 10-11.	**3rd Annual Dayton IAPPP Symposium.** Fairborn, (Dayton) Ohio. Contact: R. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.
June 11-12.	**12th Annual Apollo Rendezvous and Telescope Fair.** Dayton, Ohio. Contact: Coordinators, Apollo Rendezvous, 2629 Ridge Avenue, Dayton, OH 45414.
June 26-July 1.	**93rd Annual Meeting of the Astronomical Society of the Pacific.** University of California, San Diego — La Jolla, California. Send SASE to: San Diego Meeting, A.S.P., 1290 24th Avenue, San Francisco, CA 94122.
July 16-24.	**National Spaceweek.** Needs local organizers. Contact: Spaceweek National Headquarters, P.O. Box 58172, Houston, TX 77058.
July 18-August 8.	**International Workshop for Amateur Astronomers** (I.W.A.A.). Havelte, The Netherlands. Contact: Niels van Weersen, Sand-Ambachstraat 17, 2691 BL 's Gravenzande, The Netherlands.
July 21.	**24th Annual Summer Science Program in Astronomy.** Ojai, California. Contact: Roger D. Klauscer, Thacher School, Ojai, CA 93023.
July 21-24.	**ALCON '82** — national convention of the Astronomical League including ALPO, IAPPP, IOTA and National Deep Sky Observers annual meetings. Peoria, Illinois. Contact: ALCON '82, P.O. Box 5203, Peoria, IL 61601.
August 11-12.	**IAPPP Springfield Meeting.** Hartness House, Springfield, Vermont. Contact: R.C. Wolpert, 144 Neptune Ave., N. Babylon, NY 11704.
August 14-17.	**Stellafane.** Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Road, Sudbury, MA 01776.
August 17-26.	**XVIII General Assembly of the International Astronomical Union** (professional meeting). University of Patras, Greece. Contact: Organizing Committee, General Assembly IAU, University of Patras, Patras, Greece.

ASTRONOMY REVIEWS

Russell W. Porter; Arctic Explorer, Artist, Telescope Maker
Berton C. Willard
274 pages, hardcover, $12.50
Bond Wheelwright Company (1976)
(Order from Willmann-Bell, P.O. Box 3125, Richmond, VA 23235)

In addition to the three obsessions mentioned, you might want to add surveyor, mapmaker, cartoonist, sculptor, musician, writer, architect, calligrapher, engineer, optician and teacher. This biography documents the career of a remarkable "renaissance man" from Springfield, Vermont, whose many overlapping abilities eventually placed him at the prime focus of the 200-inch Palomar project.

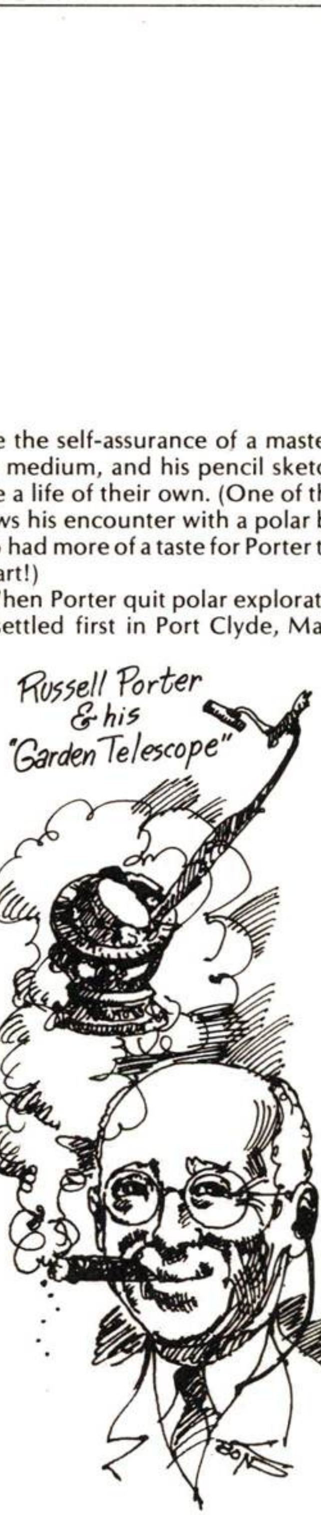
The book begins with a telling incident: the young Porter walking the suspension girders high above the rapids of the Black River "just to see what it was like." Later, when he was a young MIT student and part-time architect in Boston, Porter heard a lecture by the polar explorer, Robert Peary, that immediately fired his natural appetite for adventure.

Porter's fascination for the north — he called it "arctic fever" — led him to participate, as surveyor and artist, in nine polar expeditions over a period of 12 years. Although his experiences left him with some physical impairments (among them partial deafness), they rewarded him with reserves of self-assurance and determination that lasted the rest of his life.

Working in subzero cold with transit instruments and cranky chronometers, Porter developed an enthusiasm for designing telescopes which could be used from the snug interior of his home observatory. Later, he often compared the telescopic views of the Moon with the stark landscapes of the arctic.

His Eskimo portraits are among the finest ever painted; the watercolors have the self-assurance of a master in that medium, and his pencil sketches have a life of their own. (One of them shows his encounter with a polar bear who had more of a taste for Porter than for art!)

When Porter quit polar exploration, he settled first in Port Clyde, Maine, (where he wanted to start an artists' colony) and then later returned to Springfield, Vermont, to work for the Jones and Lamson Machine Company as their "optical associate."



By this time, Porter had become an experienced amateur astronomer and had built and outfitted a couple of home observatories. Soon, he found several like-minded individuals at Jones and Lamson and together they founded the Springfield Amateur Telescope Makers.

Porter had a gift for friendship and a true teacher's ability to inspire. His virus for shaping glass and building telescopes was highly contagious, and with encouragement and help from a number of people including Albert Ingalls — an editor at *Scientific American* — Porter inspired generations of amateur telescope makers.

Willard's description of a typical night observing session of the Springfield Telescope Makers at "Stellafane" (their clubhouse) makes you wish you were one of the select, clambering about the rocky ledges, peering through a variety of homemade telescopes, and savoring the communion of like spirits over roast pork and johnny cake.

Porter's skills in art and design also found expression in his sculptured telescopes and sundials which harmoniously blend form, function, and solid engineering. An example of the latter is the fact that the split-ring mounting, patented on his 1921 Garden Telescope, was later incorporated into the 200-inch Hale telescope.

One fine feature of this biography is a good sampling of the preliminary sketches and finished cutaway drawings that Porter made for this mighty instrument. In these drawings, all of Porter's background in art, optics, engineering, and architecture comes into play. They convey to the viewer a strong sense of how the instrument works and, at the same time, possess a powerful graphic appeal. Even his lettering is a work of art and was carefully designed into the composition. (See "The Glass Giant of Palomar: a Russell W. Porter Portfolio," p. 74, this issue.)

According to Willard, Porter's

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greatest weakness was for music — a weakness that became very clear whenever any of his own compositions was played for him. He loved the classics (especially Beethoven) and, like Beethoven, suffered from hearing problems. In total silence, Porter would enjoy reading the score of a Beethoven symphony, "playing" the music in his head. When he heard music that held no appeal for him, Porter would promptly shut off his hearing aid.

Porter's legacy includes an impressive art collection, designs for many telescopes and sundials, his contributions to the 200-inch telescope, the Stellafane gatherings, and the friendship and affection of a host of telescope makers all over the country.

Although *Russell W. Porter* lacks the stylistic beauty of Leslie Peltier's autobiography *Starlight Nights*, it gives a very clear profile of a remarkable man.

I'm left with an image of a sturdy gremlin, wreathed in smoke from a furiously stoked cigar, his head crowned with a straw hat, happily talking telescopes and stars — and inspiring so many of his surrounding disciples to look upward themselves. *Bruce Bond.*

Lumicon Giant Easy-Guider

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Livermore, CA

Lumicon's Giant Easy-Guider solves the slow-optics and porthole problems that deep-sky photographers encounter with a C11 or a C14 telescope. It also incorporates an 80mm diameter telecompressor lens big enough to fill a full 35mm film frame with an image about 2½ times brighter than normal.

In the "no free lunch" department, though, the guider is big, fairly heavy, and expensive. But it also dramatically widens a C14's capabilities for deep-sky photography. Photos I have taken with the Lumicon telecompressor on my C14 are comparable in quality to those taken with an observatory-mounted 16-inch Newtonian with a basic focal ratio of f/5.5.

The Giant Easy-Guider threads directly onto the rear cell of a C14 or C11. You can rotate it on its threads until you find a guide star conveniently placed in the camera finder and guiding eyepiece. Then you lock the guider in place with large nylon set-screws. At its rear, the guider includes an adaptor for whatever 35mm SLR body you specify. (Lumicon also offers 2¼ x 3¼ and 4 x 5 sheet film holders.)

A large prism between the telescope and the focal reducing lens — placed so it doesn't block any of the camera's field — diverts light from a guide star at the edge of the field up into a tube. This tube holds either a diagonal or an extension tube and then the guiding eyepiece.

The tube can be moved either forward or backward along the guider's body, allowing a guide star to be picked up from different sections of the prism. All in all, the guider gives you a great deal of flexibility in choosing a guide star and placing the eyepiece — something astrophotographers will appreciate.

The guider is made of machined, black-anodized aluminum. Mine squeaked, chattered, and vibrated alarmingly while I threaded it onto the rear cell of my C14, but I solved this problem by lubricating the rear-cell threads with wax from a candle stub. I found the optical quality of the telecompressor lens quite good — it delivered sharp distortion-free star images across the entire field.

Now a few nitpicks. Using nylon set-screws throughout was not a good idea. One screw on my unit was broken in shipping, and I'm worried about the three that hold the rear-plate and the camera in place. Lumicon does, however, send extra screws with the guider. (Nylon probably is best for the screws that hold the guider to the rear-cell threads since metal screws there might damage the threads.)

The prism in my unit was loose when I received it and I wasted a good deal of precious astrophotographic time — first in understanding that the prism was out of position and second in replacing it properly. Owners of the guider (or the manufacturer!) should consider cementing the prism in place once it is properly seated.

Unlike the Celestron guider, which threads to the telescope's rear cell with a separate locking ring, the Lumicon Guider threads directly on the scope. This means that rotating the guider to position a guide star changes the camera/telescope distance slightly and forces you to refocus. It's a good idea to refocus after each exposure so this is not a serious disadvantage.

The Lumicon Guider's "telecompression factor" is about 0.65. Thus the f/11 C14 becomes about f/7.1, and the f/10 C11 becomes f/6.5. Deep-sky exposures need to be moderately longer than with Celestron's telecompressor. I have found that with hypersensitized Technical Pan 2415 film, M-33 is well recorded in an hour's exposure, and M-8, the Lagoon Nebula, is nearly overexposed in 25 minutes.

In addition, accessories enable you to use a guider and telecompressor visually as a wide-field viewer. All told, the guider and telecompressor is a quality instrument that does what it claims to, and ought to be considered by those C11 or C14 owners who want to broaden the deep-sky photographic capabilities of their telescope. *David Healy.*

Editor's note: Lumicon has informed Mr. Healy that it has introduced these improvements to its Easy Guider line since his review was written.

1. The guider is now attached differently to C11s and C14s. There is a separate large-thread ring, flared like a camera adaptor flange, so that rotating the guider no longer leads to a shift in focus. This also eliminates the rattle and squeak in threading.

2. The lens has been moved a half inch farther away from the camera. This increases the compression ratio slightly from 0.65 to 0.60. In addition, you can now place the lens in front of the prism for a compression ratio of 0.5 to 0.55.

3. Lumicon has introduced a smaller model for 8-inch aperture Schmidt-Cassegrain scopes. It has the same features as the larger model.

Image et Information
Albert Bijaoui
242 pages, paperback, 140 F
Masson (1981)
[publisher's address: 133 E. 58th St., New York, NY 10022]

Intended for professional scientists, this French work deals with the mathematical processing of images. The subjects covered include statistical analysis, Fourier transforms, and digital image processing.

Practical Astronomy With Your Calculator, 2nd ed.
Peter Duffett-Smith
188 pages, paperback, $9.95;
hardcover, $29.50
Cambridge University Press (1982)

This is a revised and expanded second edition of a work first published in 1979. The book provides routines whereby anyone with a calculator or computer can derive astronomical information. Material new to this edition includes computing the date of Easter, heliographic coordinates, atmospheric extinction, perturbations of a planetary orbit, and binary star orbits.

The Fate of the Universe
Richard Morris
183 pages, hardcover, $12.95
Playboy Press (1982)

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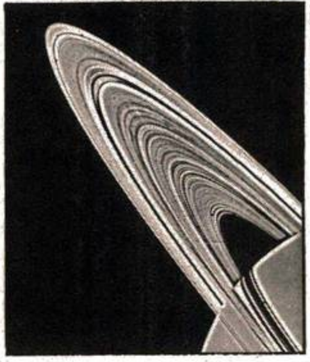
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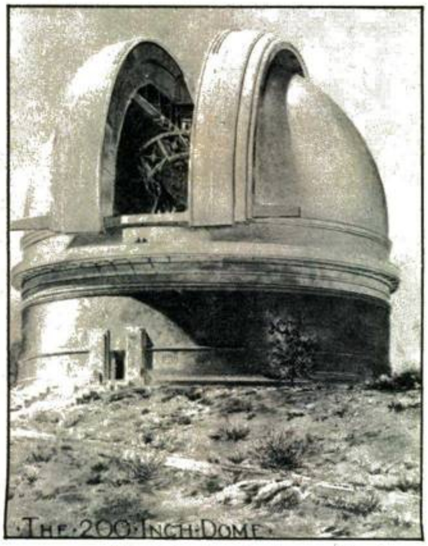
The Glass Giant of Palomar

A Russell W. Porter Portfolio

Above: Russell Porter, at left, examines a model telescope mounting at the 1937 Stellafane amateur astronomer's meeting. Photo by Robert E. Cox. Opposite page: Porter "sliced away" the dome, mounting, and telescope to show their intricate workings. Overleaf: You are standing on the west side of the mounting and looking eastward; the telescope is on the meridian and pointing south.



Porter's sketch shows the dome as seen from the northeast.

"Starlight is falling on every square mile of the Earth's surface, and the best we can do at present is gather up and concentrate the rays that strike an area 100 inches in diameter." Writing in an article for *Harper's* magazine in 1928, George Ellery Hale put his finger on the basic instrumental problem of astronomy — the cry for "more light." At that time, the 100-inch Hooker telescope at Mt. Wilson Observatory had been in use for a decade — and already its limitations were obvious. What Hale went on to propose in the same article was the construction of a still larger telescope — a 200-inch giant.

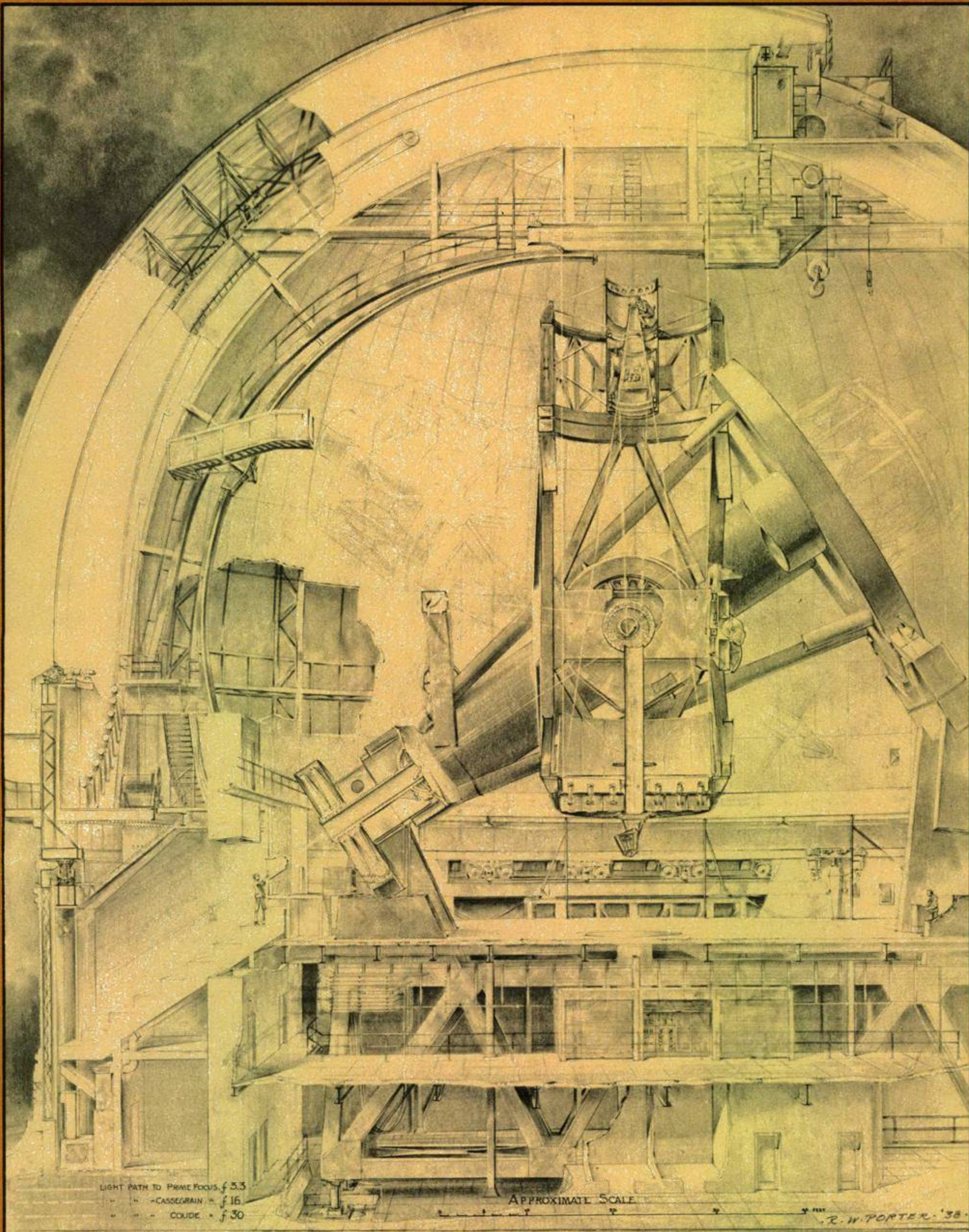
Promoting telescopes was nothing new for Hale — he started in his childhood when he successfully petitioned his father for a small refractor. By the 1920s Hale had already helped create three of the world's largest telescopes. In the 1890s he persuaded a wealthy Chicago street car magnate, Charles T. Yerkes, to buy a 40-inch refractor lens, and convinced the University of Chicago to provide the rest of the funds for what became Yerkes Observatory. In 1904 Hale founded an observatory atop Mt. Wilson, near Pasadena, California, which soon had a 60-inch reflector in operation. The mirror was provided by Hale's father, the mounting and dome by the Carnegie Institution of Washington. In 1918 a 100-inch telescope (also on Mt. Wilson) was dedicated and began its work of expanding the frontiers of astrophysics. Hale had talked John Hooker into providing the optics and convinced the Carnegie Institution to fund the rest of the housing.

The 100-inch Hooker scope had the curious effect of making the need for an even larger telescope very pressing. It had produced scientific results of great importance — among them the first extragalactic distance measurement, that of M-31 — but these had revealed new problems and created a demand among astronomers for "more light" that could only be met by constructing a bigger telescope.

After considering and rejecting a 300-inch instrument as beyond the bounds of technological feasibility, Hale settled on the 200-inch. Though it was something of a compromise with his ideal, the 200-inch telescope promised four times the light grasp of the 100-inch. It would be a great advance — and still it was well within the realm of contemporary technology.

But someone had to raise the funds to build such a huge and expensive scope. Anticipating a long, wearying fight, Hale was surprised to find the Rockefeller Foundation amenable to his request. After deliberation, they came forth with the largest single grant they had ever made — $6,000,000. With support assured, Hale began in the fall of 1928 to hire a staff that could transform the telescope from paper dreams to steel and glass reality.

Among those chosen to work on the project was a 56-year-old artist, explorer, architect, tool and die maker, and amateur astronomer named Russell W. Porter. Though Porter played less of a "hands-on" role and worked mainly at the drafting table, he nevertheless made several unique contributions. First and most important, Porter was the project's idea man. With his fine mechanical imagination and experience in working optical glass, Porter was often the one who could come up with solutions to problems that arose in the design of the instrument. He seemed to know just how to get around difficulties, almost before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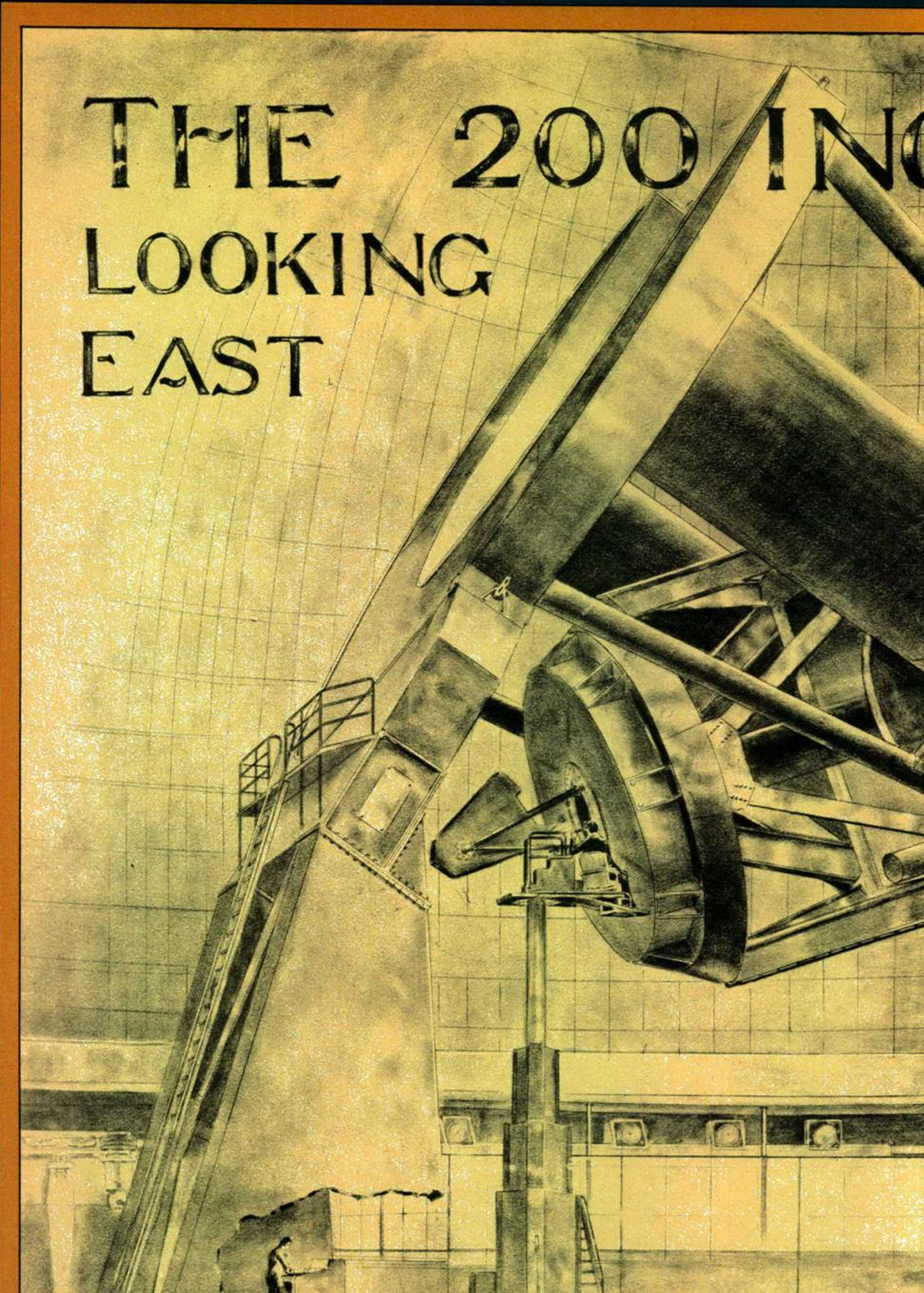
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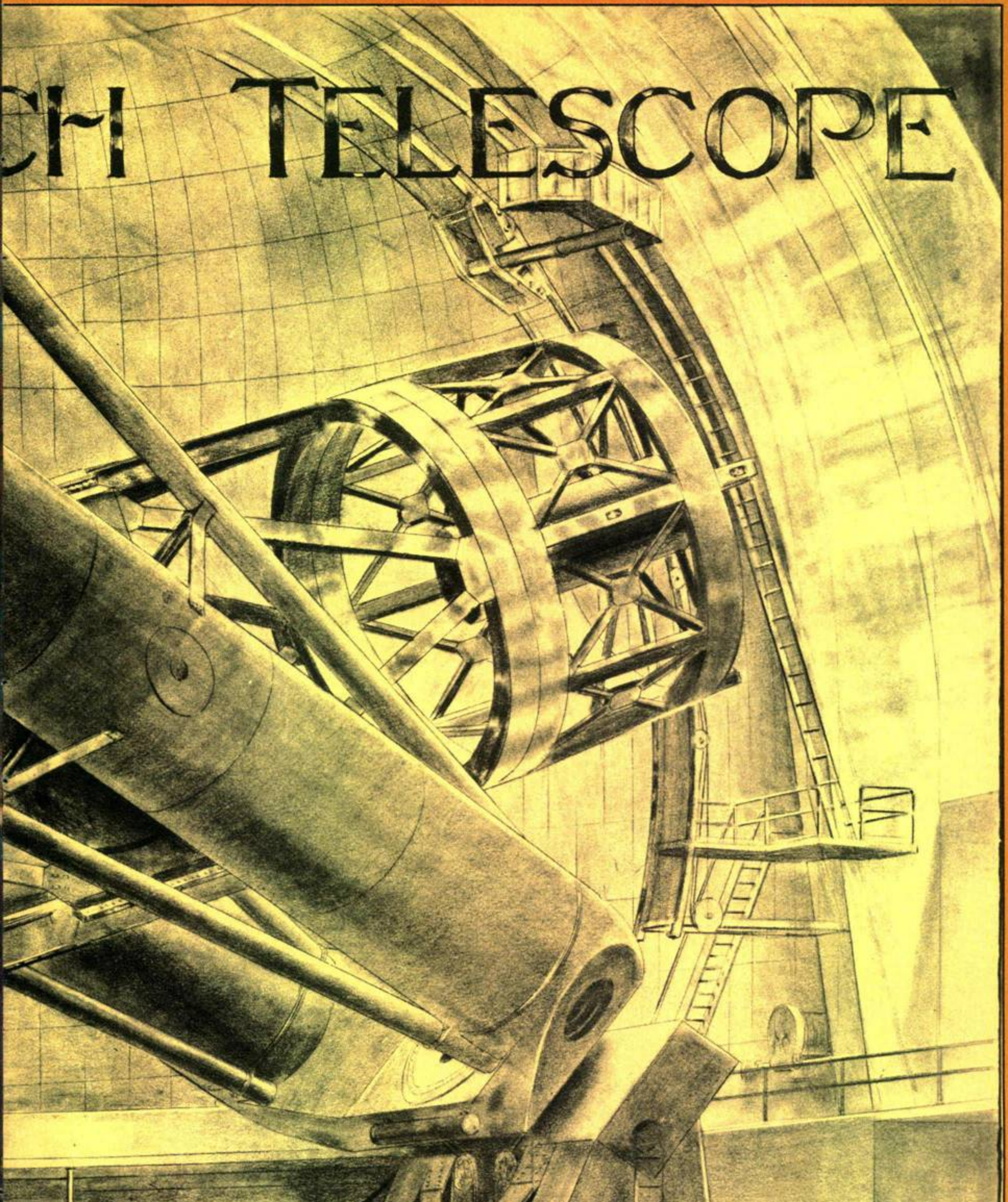
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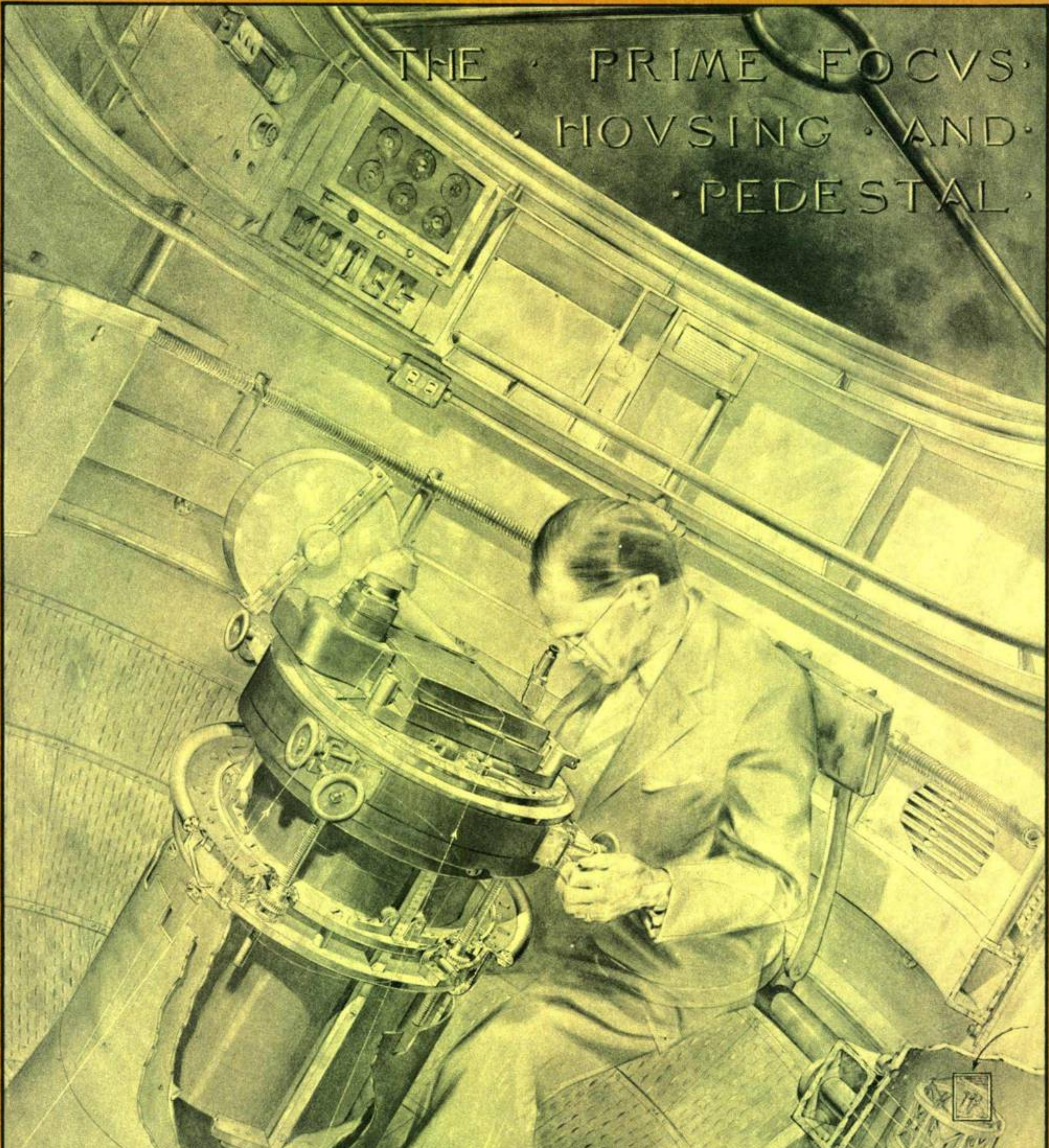
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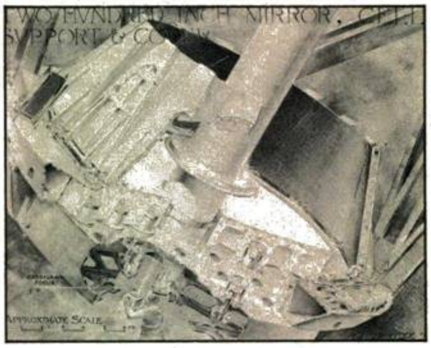
they were recognized. Second, he excelled in making diagrams — both quick sketches and magnificent cutaway drawings — which helped others visualize the complex relationships between the various moving parts of the telescope.

Made over many years and tracing the evolution of the telescope's design, Porter's drawings of the 200-inch number in the thousands, though only a few are generally seen today. Porter intended these drawings to be scrutinized carefully — and close examination shows he was meticulous in providing as full a view as possible. But his method of working was simple. He began by putting in the firm edges of objects with a fine, light pencil, taking dimensions from engineering drawings and sketches. He then drew in shadings with a softer and blacker pencil and often smudged broad areas of tone with his thumb to smooth them and provide fine texture. Lastly, Porter would add highlights with an eraser and, in some cases, white paint.

If the task Porter faced was intricate and demanding, it still yielded to simple and classic graphic techniques. The challenges confronting the others on the project were not so tractable and stemmed directly from the unprecedented size of both mirror and mounting.

The original choice for a mirror material had been fused quartz, which has a very low response to changes in temperature. But costly experiments — $600,000 worth — showed that a 200-inch mirror could not be cast for a reasonable price. The second choice was low-expansion Pyrex glass. After making several smaller mirrors to test the procedures, Corning Glass Works successfully poured the 200-inch mirror in December 1934. The blank was cooled very slowly over 10 months to remove any deforming stress in the glass; then it was sent off to the Caltech optical shop.



Above: The 200-inch mirror cell has a cork-insulated flip-down dust cover. Shown also are a few of the 36 adjustable suspension points behind the mirror. Opposite page: An observer working at the prime focus rides in a small "cage" mounted on the telescope.

In California the mirror blank was placed on a specially-constructed grinding machine that proceeded to work its surface into the shape chosen. Four tons of glass were removed as the center of the mirror was deepened five inches to yield a focal length of 660 inches. Grinding the mirror to a sphere was done rapidly, but parabolizing and polishing took far longer — and the intervention of World War II halted all work on the project. Finally, in November 1947, the mirror was delivered to the waiting dome and mounting on Mt. Palomar.

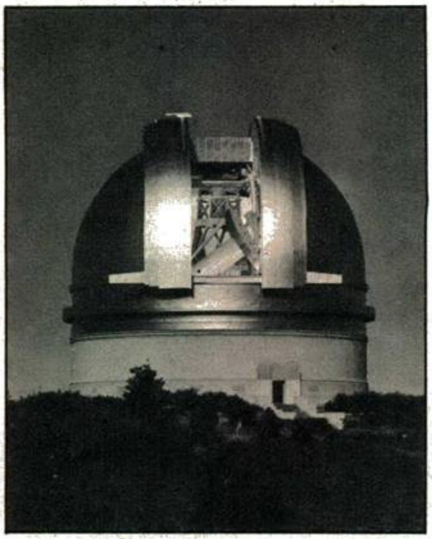
The mounting posed as many difficult problems as casting and grinding the mirror. The first plans called for a fork mounting, but studies showed that such a design would not remain sufficiently rigid. The alternative was the sturdy yoke type, but this design (used on the 100-inch) prevented the telescope from pointing very near the pole. In the end, the design chosen — one that owed much to Russell Porter — was basically a yoke with a horseshoe-shaped north bearing that contains a wide "slot" that accommodates the scope when it is pointed directly north.

Another problem was how to aim such a huge telescope. The engineers considered ball and roller bearings, but rejected them when calculations showed that only extremely powerful motors could move the scope. Then two engineers came up with a successful plan to "float" the telescope on a film of oil between the bearing surfaces. An oil pressure of about 250 pounds per square inch, maintained by pumps, lifts the telescope a few thousandths of an inch, reducing the friction enough to let a puny half-horsepower motor drive the entire 500-ton telescope.

The third big hurdle was keeping the optical elements in alignment — to within 0.08 inch — regardless of the tube's orientation. Holding a movable steel structure rigid to this degree over a length of 55 feet simply isn't possible. Instead, the structure was engineered so that as its two ends sagged, they both sagged the same amount, and thus preserved their alignment. This clever approach — named the Serrurier truss after the engineer who designed it — is now used on all large telescopes.

Three months after the mirror and mounting were joined, the first test observations were made. Six months later, in June 1948, the official dedication ceremony proclaimed the 200-inch as "the Hale Telescope," to honor the man who created it — but who had died in 1938.

Since then, the 200-inch has more than fulfilled the promise Hale saw in it over half a century ago. Both the Hale scope, and the other "glass giants" that now accompany it, have created observational cosmology. Nor should we think its revolutionary findings are all past. New and sensitive instrumentation has extended the Hale scope's light-grasp much farther than its designers dreamed. And as with quasars 20 years ago, we can expect that the future will add entirely new classes of objects to our knowledge — objects whose study will demand its immense light-gathering capacity. The story of the 200-inch — now 54 years in the making — is far from over.



The 200-inch and dome by moonlight. This photograph and all Porter drawings are courtesy of Hale Observatories.

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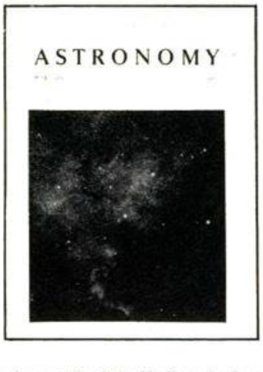

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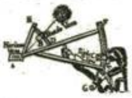

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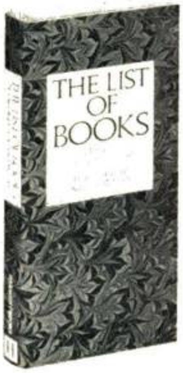

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WANTED — Correspondence with persons, all ages, interested in astronomy, cosmology, astrophysics, anthropology, archaeology, astrophotography, diagammes, science fiction, computers, UFO reports. Foreign correspondents welcomed. Contact A. McKinley, c/o P.O. Box 161815, Sacramento, CA 95816. Phone (916) 444-6165.

WANTED — People interested in astronomy and/or telescope making in the greater Burlington, Vermont, area or Chittenden County region. Contact Larry Laforge, President, Vermont Astronomical Society, 1 Sebring Road, South Burlington, VT 05401. Phone (802) 864-5850.

WANTED — Computer programs for astronomy. I have programs for time conversions, coordinate conversions and star catalogs. Send SASE for free programs. Would like to see yours, too. Contact Stephen Kysor, 11782 Bluejay Lane, Garden Grove, CA. Phone (714) 537-0521.

WANTED — October 1973 issue of ASTRONOMY. Must be in excellent condition. Contact George R. Bonnett, P.O. Box 189, Douglas, AK 99824.

WANTED — Small observatories to make observations for professional astronomers. Contact International Amateur-Professional Photoelectric Photometry (IAPPP) Association, 1247 Folk Road, Fairborn OH 45324.

WANTED — *Explorer of the Universe* by H. Wright, *Sur les Autres Mondes* by L. Rudaux, *Atlas of the Selected Regions of the Milky Way* by E.E. Barnard, *Astronomy of the 20th Century* by D. Struve and V. Zebergs, and *Reminiscences of an Astronomer* by S. Newcomb. State condition and price. Contact Bruce Bond, 8050 N. Port Washington Rd., Milwaukee, WI 53217. Phone (414) 351-2326.

WANTED — Correspondence with persons (ages 15 and over) interested in astronomy, psychology, cosmology, and reading. Contact Phil DiAntonio, 474 Fifth Ave., Barrington, NJ 08007.

WANTED — retired locomotive engineer would like to correspond with others who also own a Dobsonian alt-azimuth telescope so we can exchange some ideas. Contact Joe Russell, 55 Strawberry Lane, Nordland, WA 98358.

WANTED — Correspondence with anyone interested in science, astronomy, sci-fi and fantasy, movies, war games and more. Earthlings preferred, but will answer all letters. U.S. contacts preferred. Contact Joel Kincaid (age 17), 67 Chestnut St., Wilmington, MA 01887.

WANTED — Parts and accessories for Tinsley 8- Cassegrain: 3- guide scope, filar micrometer, eyepieces, astro-camera, manuals, etc. Also 5- and 12-. Contact Bill Brockmeyer, 1454 Yale St., #7, Santa Monica, CA 90404. Phone (213) 829-2423.

WANTED — Correspondence with any professional astronomer on publications, books, information, etc. I am interested in becoming an astronomer. Also correspondence with any amateur astronomers. All correspondence will be appreciated. Contact Duane Baisley, P.O. Box 21, Lake Peekskill, NY 10537.

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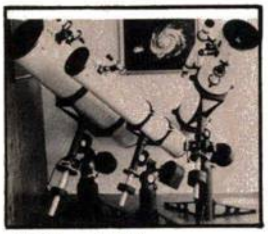

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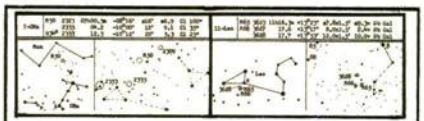

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WANTED — Astronomical programs for Apple II Plus computer. Also Arp's *Atlas of Peculiar Galaxies* and Vorontsov-Velyaminov's 5 volume *Morphological Catalog of Galaxies*. State condition and price. Contact Randy Trank, 1307 15th Ave., Rockford, IL 61108. Phone (815) 226-0531.

WANTED — Antique instrument enthusiast seeks telescopes, micrometers, transits, sextants, microscopes, etc., or parts thereof, particularly a working filar micrometer. Also wanted: printed matter related to history of astronomy, and old astronomical books and maps. Contact J. Briggs, Box 311, Westport Point, MA 02791.

WANTED — C-90 telephoto or spotting scope, off-axis guider, illuminated crosshair reticle, Gemini Twin Track or Accutrack with auto guide. Must be reasonable. Also correspondence with person (25 and up) in South America or Japan. Contact Charles Bunting, Box 144, Shambaugh, IA 51651.

WANTED — Suitable position for radioanalytical/inorganic chemist (Ph.D. 1979). Experience includes meteorite analysis, environmental chemistry and crystal growth. Resume, references and list of publications available upon request. Contact Dr. Richard Muntean, 34455 Park East Dr., Apt. B-105, Solon, OH 44139.

WANTED — Slides of objects in the solar system for use in my junior high science classes. Prices must be low. Especially need those of asteroids, meteors, Mercury, Uranus, Neptune. Contact Robert Frostick, Box 369, Smithers, WV 25186.

WANTED — 6- reflector or 3- to 4- refractor for $250 to $300. Contact Brian Marcey at 10829 Mt. Vineyard Ct., Fairfax, VA 22032.

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ANNOUNCEMENT — The Baton Rouge Council on Space is coordinating pro-space activities in Louisiana, Mississippi, and Texas. Write or phone Greg Floyd, Box 22896, LSU, Baton Rouge, LA 70893; phone (504) 334-3482. Or phone Joey Robichaux, (504) 293-6674.

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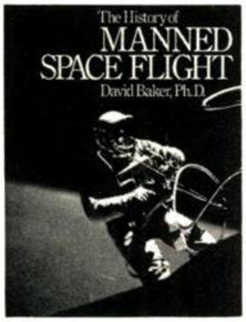
by David Baker



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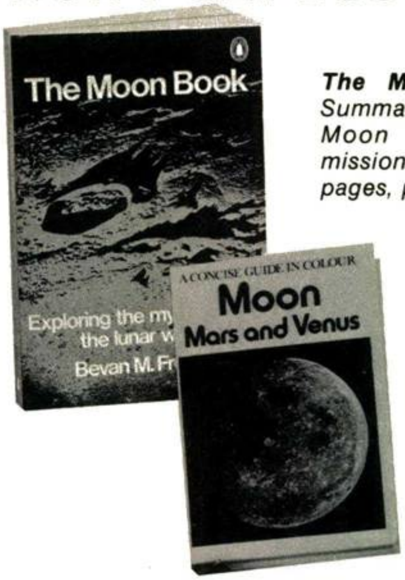

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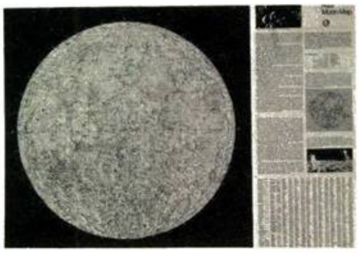

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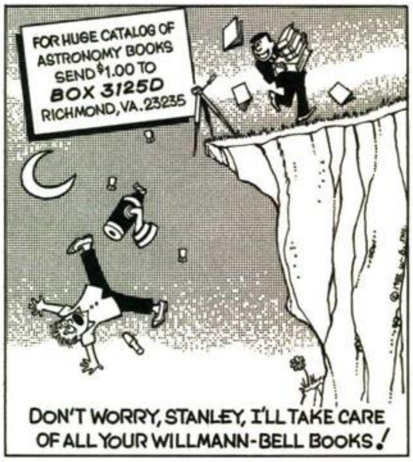
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ANNOUNCEMENT — The Miami Valley Astronomical Society and the Dayton Museum of Natural History present the 12th Annual Apollo Rendezvous and Telescope Fair, June 11 and 12, 1982. For more information contact: Coordinators, Apollo Rendezvous, 2629 Ridge Ave., Dayton, OH 45414.

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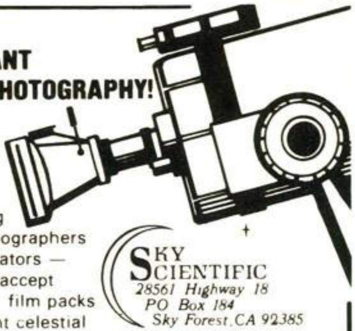

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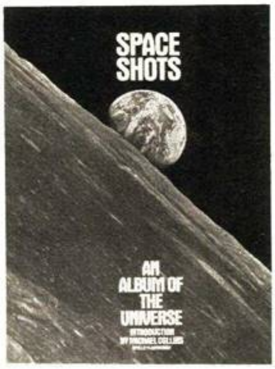

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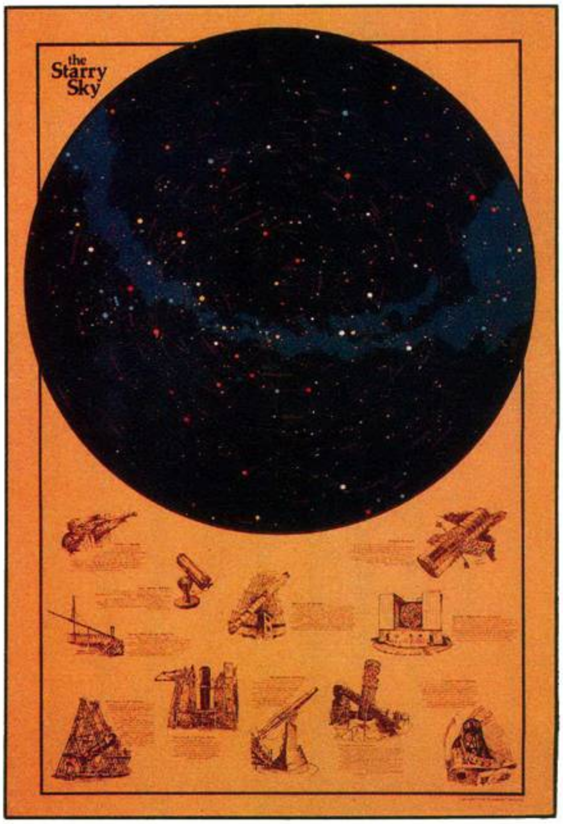

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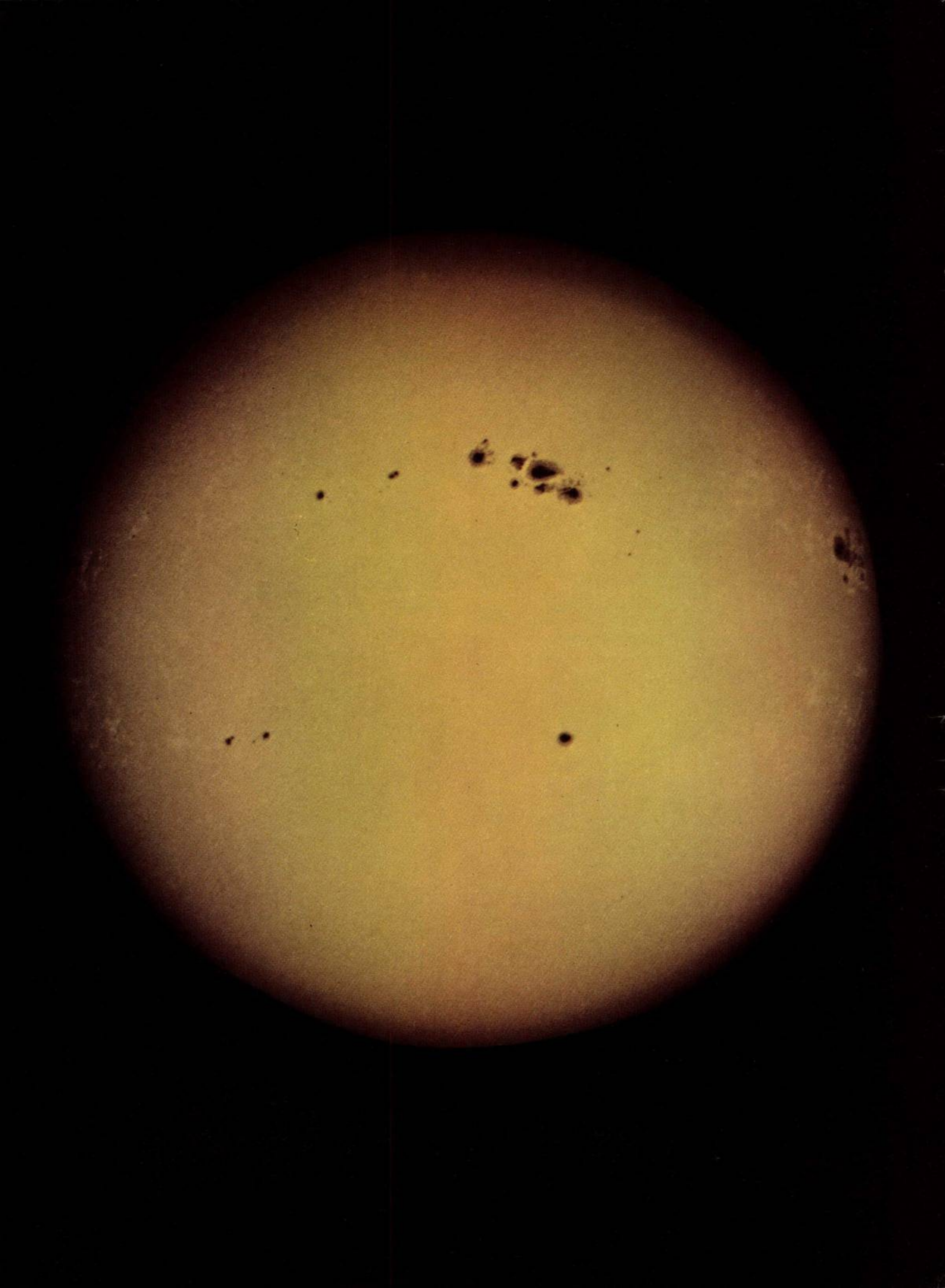


the backyard astronomer

libra

May will provide many fine planetary sights: Mercury is visible in the west after sunset during the first part of the month; Mars, Saturn, and Jupiter are arrayed across the sky in the late evening hours; and Uranus and Neptune both rise before midnight.

Mercury

Evenings in the first three weeks of May will see the second half of this year's best Mercury apparition. Reaching greatest elevation over the west-northwestern horizon on May 8, a day before greatest elongation, the planet will sink lower every evening until it disappears into the solar glare around the 25th. Mercury's diminutive size (7.9" of arc at elongation) and its low elevation (11°, 45 minutes after sunset) assure its elusiveness.

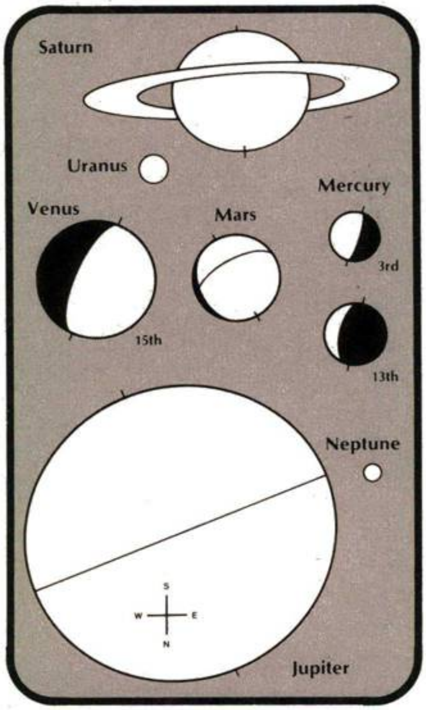
Since it has a surface much like our Moon, the small planet's features lack contrast and would be hard to pick out in a telescope even if it weren't so close to the Sun. The best approach for a telescope user is to locate it as early in the evening as you can and observe while skylight still surrounds the planet. Mercury's higher position will then minimize the thick blanket of air you look through. The reduced contrast between Mercury and the sky may also help you see faint details on the disk.

Venus

Around the middle of May, Venus reaches its lowest elevation in the morning sky until the second week of August. Although it isn't much higher than Mercury is in the evening sky, this shrouded planet shines far more conspicuously. (Compare their magnitudes in the Planetary Data table on page 88.)

The face of the Sun on October 13, 1981, revealed several dark sunspot groups and bright plages at low solar latitudes; south is at top. A.W. Steinbrecher's photo — winner of the May '82 "Best Astro-Photo" award — was taken with a 6-inch telescope. He used a solar filter, 2415 film, and 1/125-second exposure at f/13.

With its gibbous appearance and bland, brightly reflective disk, Venus doesn't show much detail through the telescope. But ultraviolet readings from spacecraft indicate that the venusian atmosphere has distinctive features. Although our eyes aren't sensitive to those wavelengths, and Earth's atmosphere absorbs them strongly, careful observation using blue and violet filters has sometimes revealed faint and indefinite markings in the cloudtops.



The best time to look for these features is when the skylight around the planet is relatively bright. By not swamping your eye with the contrast between bright planet and dark sky, you'll sharpen your ability to discern subtle contrasts on the planet itself.

Mars

Mars spends most of May in the northern celestial hemisphere, but after it resumes direct motion on May 13, it crosses the equator southbound and remains in the southern celestial hemisphere until late next February.

Mars' brightness decreases rapidly over the next few months as its distance from Earth increases. It is also moving toward the more southerly declinations that are harder to observe from northern latitudes.

Asteroids

1 Ceres (magnitude 6.8) is moving almost due westward in Libra. On the 12th at 11:11 UT, Ceres will pass 10′ of arc north of the 2.6 magnitude star Beta (β) Librae. Its positions:

9th: 15h 17m 32s, -9° 02.4′
19th: 15h 08m 18s, -9° 02.8′

Ceres is at opposition on May 10th.

2 Pallas (8.0) lies in central Coma Berenices. During the first week of May, it will be passing near to 9th magnitude M-64, the "Black-Eye" Galaxy. Its positions:

9th: 12h 52m 27s, +22° 17.7′
19th: 12h 50m 35s, +22° 47.6′

Pallas sets around 4:30 a.m. local daylight time at mid-month.

3 Juno (10.6) lies in Scutum near the border with Serpens Cauda. Its positions:

9th: 18h 35m 52s, -6° 29.8′
19th: 18h 32m 52s, -5° 51.0′

Juno rises around 11 p.m. local daylight time on the 15th.

4 Vesta (7.4) is in eastern Capricornus, just to the west of 3rd magnitude Delta (δ) Capricorni. Its positions:

9th: 21h 14m 49s, -16° 43.8′
19th: 21h 26m 39s, -16° 22.0′

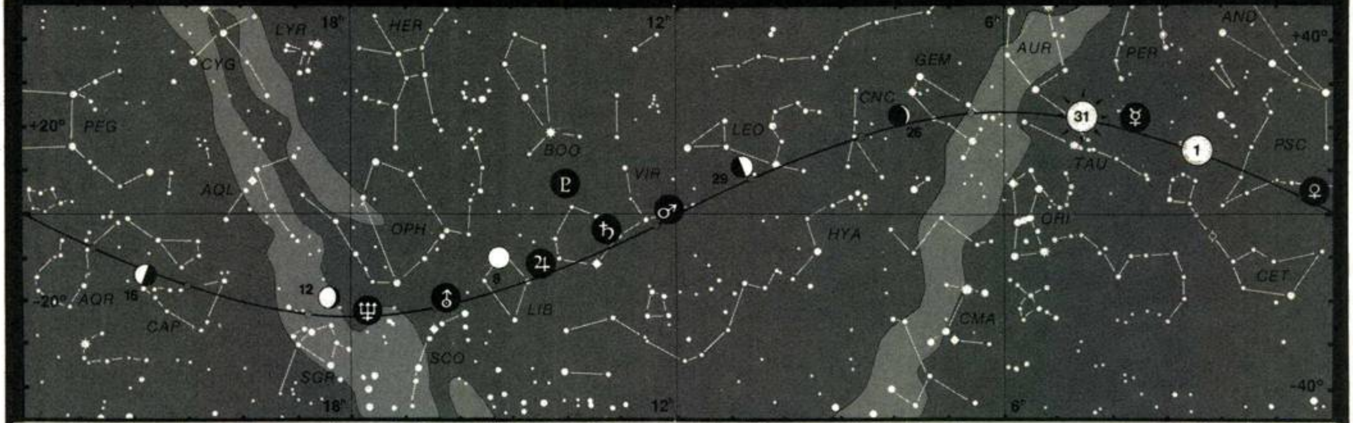
Vesta rises at about 2:30 local daylight time in the middle of the month.

(All asteroid positions are in 1950.0 coordinates.)

Jupiter

Watching the changing weather on

planetary data may 1982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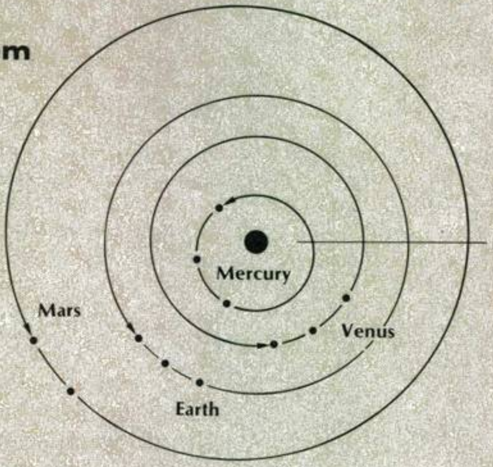
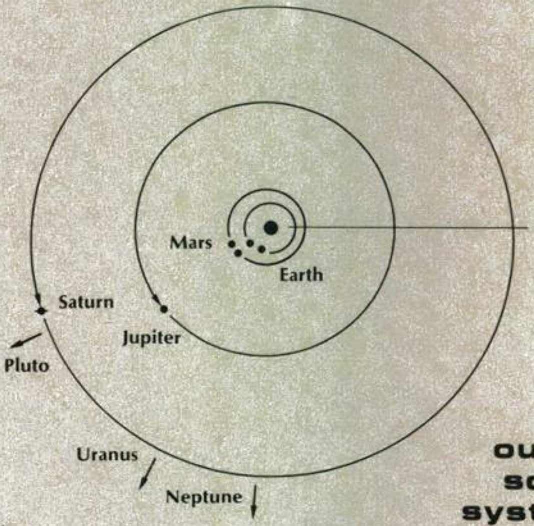

Mercury
Mars
Venus
Earth


Mars
Earth
Saturn
Jupiter
Pluto
Uranus
Neptune

outer solar system

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from:		Longitude:		R.A. (1982.4)	Dec
						Earth	Sun	Heliocentric	Ecliptic		
Sun		1	-26.7	31.8′	—	1.01	—	—	40°18.6′	2h 31.5m	+14°54.6′
		15	-26.7	31.7′	—	1.01	—	—	53°51.2′	3h 25.9m	+18°44.1′
		31	-26.7	31.6′	—	1.01	—	—	69°14.4′	4h 30.2m	+21°50.2′
Mercury	☿	1	-0.3	6.5″	61%	1.03	0.34	136°43.6′	58°42.0′	3h 45.6m	+22°11.9′
		15	+1.2	9.3″	22%	0.72	0.41	197°26.9′	69°36.1′	4h 48.1m	+24°28.8′
		31	+3.2	12.1″	0%	0.55	0.46	245°58.4′	71°32.4′	4h 42.9m	+20°25.7′
Venus	♀	10	-3.6	17.2″	67%	0.98	0.73	295°21.6′	5°42.4′	0h 25.0m	+0°59.1′
		31	-3.5	14.8″	74%	1.13	0.73	328°34.8′	29°42.1′	1h 55.1m	+9°34.8′
Mars	♂	15	-0.4	12.1″	93%	0.77	1.60	211°01.8′	180°08.5′	12h 03.6m	+0°55.9′
Jupiter	♃	15	-2.0	44.0″	100%	4.48	5.43	216°54.4′	212°41.9′	14h 05.6m	-11°13.5′
Saturn	♄	15	+0.7	18.8″	100%	8.86	9.68	200°05.4′	196°00.7′	13h 04.8m	-3°57.7′
Uranus	♅	15	+5.8	3.8″	100%	17.88	18.88	242°30.7′	242°30.5′	16h 03.9m	-20°36.0′
Neptune	♆	15	+7.7	2.5″	100%	29.42	30.27	265°28.4′	265°59.4′	17h 44.9m	-22°04.9′
Pluto	♇	15	+13.8	—	100%	29.12	29.96	205°45.5′	204°22.5′	13h 57.4m	+6°46.7′

moon data

Full Moon	May 8 at 00:45
Last Quarter	May 16 at 05:11
New Moon	May 23 at 04:40
First Quarter	May 29 at 20:07
Full Moon	June 6 at 15:59
Last Quarter	June 14 at 18:06
Apogee: May 11 at 15h	405,433 km
Perigee: May 24 at 3h	358,807 km

universal time

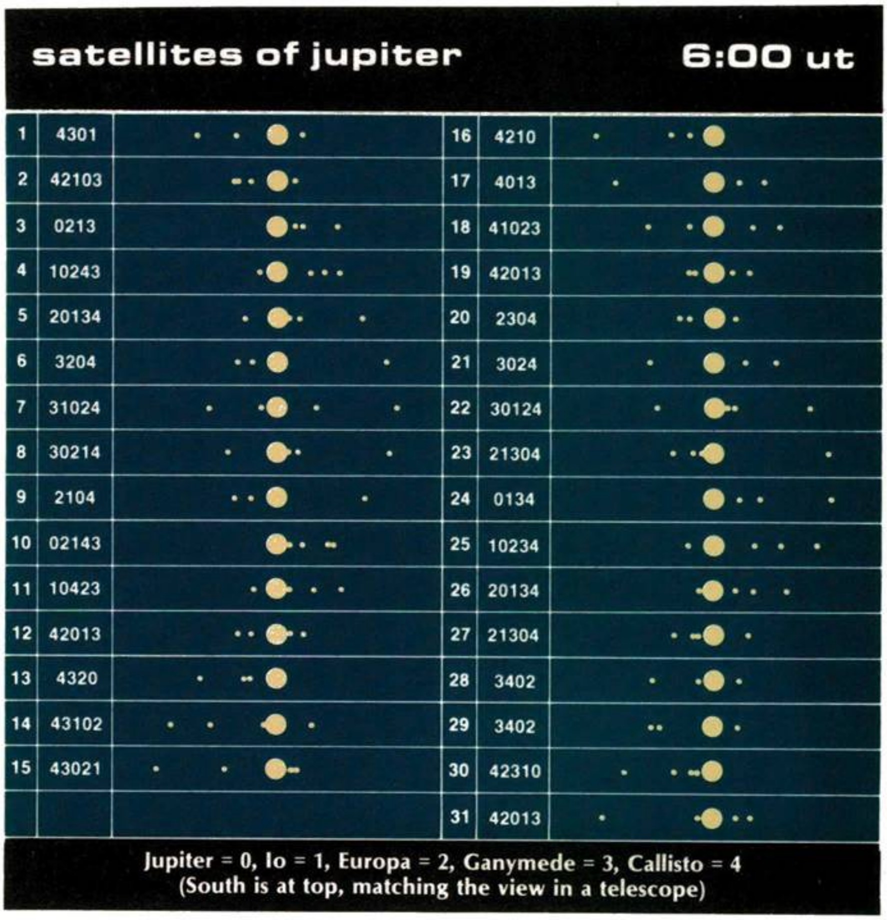
Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times given in The Backyard Astronomer are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then EDT for the event is 11 p.m., June 6. Likewise, 03:00 UT on September 2 becomes, in PDT, 8 p.m., September 1.

M-106 is an 8th magnitude spiral galaxy in Canes Venatici. It lies about halfway between Beta CVn and Gamma UMa. Some 25 million light-years distant, this galaxy is a strong source of radio emission. Jack Newton took its portrait with a 16-inch f/5 telescope, a cold camera and a 14-minute exposure on ASA 400 film.

Jupiter is only part of the fun of looking at this giant planet. Another delight is following the motions of its four brightest moons, Io, Europa, Ganymede, and Callisto. Discovered by Galileo in 1609, these moons sweep regularly around Jupiter and from time to time pass across the face of the planet (transit) or duck behind it (occultation).

Innermost and fastest moving of these four moons is Io (5.5 magnitude); it circles once every 1.77 days. Next outward is Europa (6.1 m), which orbits in 3.55 days. Then comes Ganymede (5.1 m), the biggest and brightest of the four, completing one orbit every 7.15 days. Last is Callisto (6.2 m), circling once every 16.69 days.

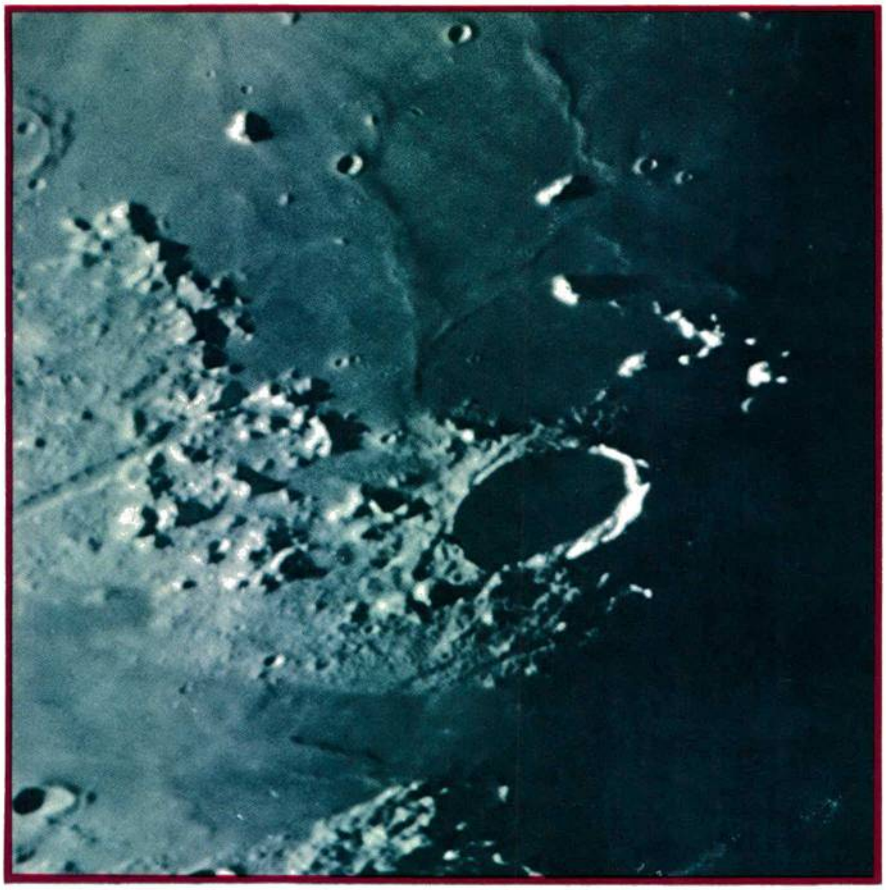
Since Io orbits the quickest, it has the greatest number of events. A typical transit event proceeds as follows: at 3:05 UT on May 14, it will start a transit across the jovian disk. At 3:30 UT, its shadow will appear on the disk also and follow the moon. Io



satellites of jupiter 6:00 ut

1	4301	16	4210
2	42103	17	4013
3	0213	18	41023
4	10243	19	42013
5	20134	20	2304
6	3204	21	3024
7	31024	22	30124
8	30214	23	21304
9	2104	24	0134
10	02143	25	10234
11	10423	26	20134
12	42013	27	21304
13	4320	28	3402
14	43102	29	3402
15	43021	30	42310
		31	42013

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)



Left: The lunar Alps are rugged mountains along the northern edge of Mare Imbrium. Early morning shadows reach across the floor of the large crater Plato in Jean Dragesco's photograph. Right: Orien Ernest took this photo of the North America Nebula with the astrophotography outfit he describes on page 52.

leaves the disk at 5:14 UT, and the shadow's transit ends at 5:40 UT.

Europa has fewer events, but the sequence listed for Io will happen to this moon on May 1. The times will be: 5:12, 5:25, 7:33, and 7:51 (all UT). In a different type of event, on the 10th at 2:30 UT, Europa will disappear behind the western limb of Jupiter. At 5:35 UT, it will reappear from the planet's shadow on the eastern side, some distance away from the planet itself.

Ganymede's events are even rarer. This moon will disappear behind Jupiter at 2:40 UT on the 9th and will reappear out of eclipse at 6:02. Callisto orbits far from Jupiter and, from our point of view, now passes to the north of the planet's disk (when in front of Jupiter) or to the south of its shadow (when behind). Accordingly, no transit or occultation events occur for it this year.

Saturn

The saturnian satellite system doesn't have a bright family like that of Jupiter. Saturn's brightest moon is Titan (8.4 magnitude) and it has no companions in its class. Titan is easy to locate even in a small telescope. Taking almost 16 days to circle Saturn, this haze-shrouded moon is at greatest eastern elongation from the planet on May 4 at 7:30 and May 20 at 5:24 (all times are UT).

The next brightest of Saturn's moons is Rhea, which shines at 9.7 magnitude. Its orbital period is 4½ days and it will be at eastern elongation on: May 1 at 8:18; 5th at 20:36; 10th at 8:54; 14th at 21:18; 19th at 9:42; 23rd at 22:00; and 28th at 10:24 (all times are UT).

Neither Titan nor Rhea will exhibit transit or occultation phenomena this year because we are seeing the Saturn system tipped at about 10° from edge-on. As with Callisto at Jupiter, we see these moons pass above or below the disk and its shadow.

Sometimes it's hard to tell a satellite from a background star. The best method to distinguish between the two is to make a sketch (or photograph) on one night and compare it with the placement of the "stars" on the next few nights. In general, stars will slide smoothly day by day through your field of view, while the closed orbital motion of a satellite will soon show itself.

Uranus

On May 4, Uranus will complete its passage "through" the two stars that make up Omega (ω) Scorpii. At 3:27 UT on that date, it will lie 3'37" south of Omega^1. Medium to high powers will easily reveal the disk of the planet, 3.8" of arc across.

After passing Omega^1, Uranus will continue its west-northwestern course. By the end of May, it will lie about a degree to the west of the Omega Sco pair.

Neptune

At magnitude 7.7 and with a 2.5" of arc disk, Neptune is fairly easy to recognize when you find its field. Locate the 4.9 magnitude star 58 Ophiuchi in a star atlas and then scan half a degree south. At the beginning of May, Neptune lies 4m of right ascension to the east; by the end of May, only 1m.

Meteors

The chief shower in May comes early in the month. Reaching its peak activity on the 3rd, the Eta Aquarids arrive with an average hourly rate of 10 to 20. The parent of the swarm is the famous Comet Halley.

The greatest number of meteors will be seen in the predawn hours of the 3rd, with the radiant located — as the shower's name suggests — near the star Eta (η) Aquarii. Unfortunately, the Moon won't set until shortly before morning twilight begins — so the fainter Aquarids will be lost in its glow.

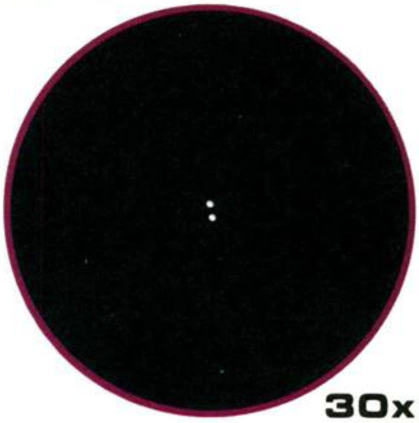
close-up on libra

Libra, the zodiacal scales, is often neglected by skywatchers because it has few bright stars. Most beginning astronomers have a hard time just picking out the area of Libra. It's no wonder, because in addition to having faint stellar members and a southerly locale, it is widely spread and loses many of its members to the light pollution of today's cities.

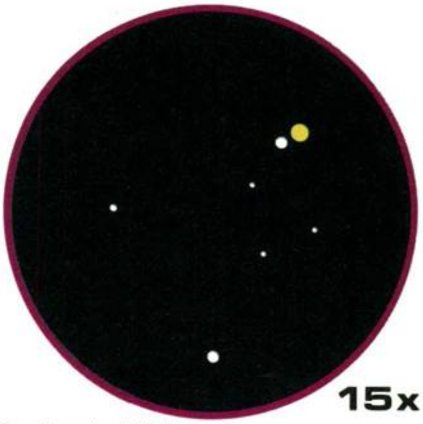
The naked-eye stars Alpha, Beta, Gamma, and Iota form a large diamond shape symbolic of a balance. To the Greeks this constellation was a part of Scorpius, as the diamond shape made a good pair of claws for the beast. Webb recounted his feelings for Libra in this passage: "the southerly declination combines with long days and late sunsets to give trouble in looking for the objects in this constellation, which are, however, well worth the pains."

Alpha (α) **Librae**, or Zuben El Genubi, "the southern claw," marks the western corner of the diamond and lies almost square on the ecliptic. This sun is actually a wide binocular pair of third and fifth magnitude stars (Alpha^2 and Alpha^1), separated by 230 seconds of arc — nearly four minutes apart. Any optical aid, even opera glasses, will separate the two components. Alpha is a type A3 star about 65 light-years from us and nearly 25 times brighter than our Sun. In 1966 astronomers determined that the main

Struve 1962



Alpha Librae



Drawings by J. Mullaney

sun itself was a spectroscopic binary. This observation was verified by astronomers using the 36-inch reflector at Kitt Peak National Observatory. Astronomers estimate the orbital period to be around 20 days, but this has never been verified.

Beta (*β*) **Librae**, or Zuben Escamali, "the northern claw," is a 2.6 magnitude object lying at a distance of 140 light-years, and is actually 145 times brighter than the Sun. As an added treat, on May 12, the asteroid Ceres will pass close to Beta. See "Asteroids" on p. 87.

You might have noticed that Beta is brighter than Alpha. How can this be? There has been a classic controversy over the alleged brightness change of Beta Librae since the time the ancients made the original magnitude estimates. According to Robert Burnham, Jr., Eratosthenes had determined it to be the brightest star among all the suns of Scorpius and Libra. Several centuries later, Ptolemy found it equal to Antares. Recent researchers think that maybe Antares is the one that's changed.

Still another mystery surrounds the true color of this star. Although listed as spectral type B8, it has aften been described as "greenish" or "emerald." Webb referred to its "beautiful green hue," and Olcott determined it to be "the only naked eye star that is green in color." Webb went on to say that he "inserted it for its beautiful pale green hue, very unusual among conspicuous stars; deep green, like deep blue is unknown to the naked eye." Barns dubbed it a "pale emerald unit resembling Uranus." Muirden was a bit more skeptical: "It has somewhat a greenish tinge, but not at all obvious on a casual glance." Star colors are extremely elusive, and modern observers generally agree that the only stars that appear definitely greenish are the close companions of red stars, such as Antares. According to Burnham, if Beta Librae is truly green, it is the only bright, single star that is.

Delta (*δ*) **Librae** is a bright eclipsing Algol-type variable that Schmidt discovered in 1859. Its range in magnitude is from 4.8 to 5.9. and it has a period of 2.3 days. The star is about 225 light-years from us and its components are separated by 4.5 million miles. The "winking" effect is easy to see even in binoculars as it only takes six hours for the star to drop to minimum.

Most of the time Delta is brighter than 5th magnitude, but when it drops, you will need binoculars to see it. When Schmidt discovered its period he commented that he thought it was increasing slightly. History has proven him correct; it is now generally accepted that period changes in eclipsing binaries are the norm. Studying these changes provides details on the dynamics of the system. Observers interested in monitoring these type of changes over a period of time should contact the American Association of Variable Star Observers (AAVSO), 187 Concord Ave., Cambridge, MA 02138. For casual monitoring use the 4.9 magnitude star Epsilon (*ϵ*) that lies two degrees southeast of Beta as a magnitude check. Keep an eye on these unusual paired suns and imagine what it would be like if our Sun were a double.

Our next offering and the last star in the diamond shape is the triple star system of **Iota** (*ι*) **Librae**. Iota is a 4.7 magnitude star lying at a distance of 250 light-years. That gives it an actual luminosity of 60 times the Sun. It is a very close visual binary that went unnoticed until 1940. Splitting the star is very difficult and only larger scopes will do it.

Classic observations like those of Olcott and Webb listed this star as simply a wide unequal double of magnitudes 4.7 and 9.7 with a separation of 59 seconds. Olcott described it as "yellow-purple" and said it was difficult to resolve in his three-inch refractor. Barns also regarded it as a double calling its components "wide guide stars to the cluster NGC-5897."

Burnham discovered the true nature of the system when he used his 6-inch refractor to divide the fainter component into two stars of tenth magnitude only 1.8 seconds apart. The position angle of these two stars decreases slowly, indicating a binary with a very long period. For the record, Iota Librae is actually a grouping of four stars all orbiting around a common center of gravity.

Only 1.7° to the southeast lies the very large, loose and dim globular cluster, **NGC-5897**. Use a low-power eyepiece after locating Iota to help you find this elusive quarry. This globular is about seven minutes in size and shines at 8.6 magnitude. For a globular it is not very compact and is classified as poor in its concentration of stars. You can see it easily in a 4-inch at 45 power, but to resolve its outer edges, you'll need at least an 8-inch at 100 power. Webb described it rather unenthusiastically as a "globular cluster of small stars," while Muirden logged it as "large and dim." Barns mistook it for HV-19 and described it as "a universe of remote suns" as seen through his 10-inch reflector. In the *New General Catalogue*, it is listed as a "globular cluster, pretty faint, large, very irregularly round, very gradually brighter in the middle, well resolved, clearly consisting of stars." This account is by Herschel — its discoverer.

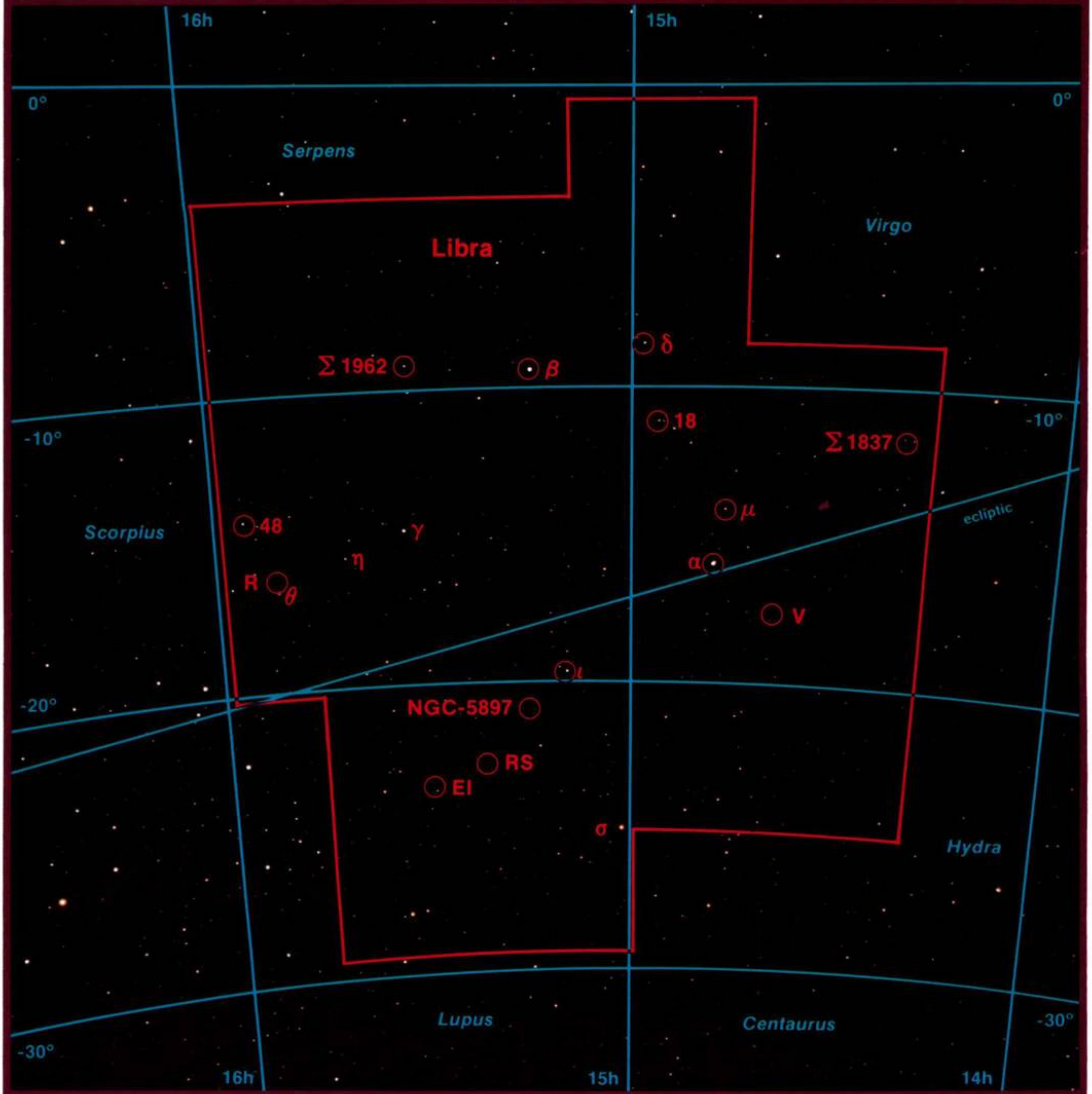
NGC-5897 is another one of those lost and forgotten globulars since it lies in such close proximity to the wealthy regions of the summer Milky Way. If you want to see all the globulars in the sky, you'll have to work for this one.

Shifting back over toward Beta, you'll find another interesting double star. **Struve 1962** lies 5½° east and ½° north of Beta Librae. You can even split it with a 2-inch scope at 30 power. This pair consists of a nearly perfectly matched set of whitish suns at magnitude 6.5 and 6.6 about 12 seconds apart. Webb called it a "striking object." Take a look for yourself — it's not often you'll see two matched suns glowing in the field of a low-power eyepiece.

Now let's move on to a bizarre object — **48 Librae**, a magnitude 4.9 star. 48 Librae is a blue-white star about 450 times the Sun's luminosity and five times the diameter. It is 640 light-years distant. The star is surrounded by a shell of turbulent gases which occasionally shows expansion of 60 miles per second! Last reported activity of this nature was in 1967. Many different elements have been detected in the shell and may indicate some sort of stellar instability. This strange object appears to be a single star and displays only slight variations in its light output — compared with similar stars. Why not track down this interesting object tonight?

libra

photo by B. Wallis and R. Provin


16h
15h
0°
0°
Serpens
Libra
Virgo
δ
Σ 1962
β
18
Σ 1837
-10°
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Scorpius
48
γ
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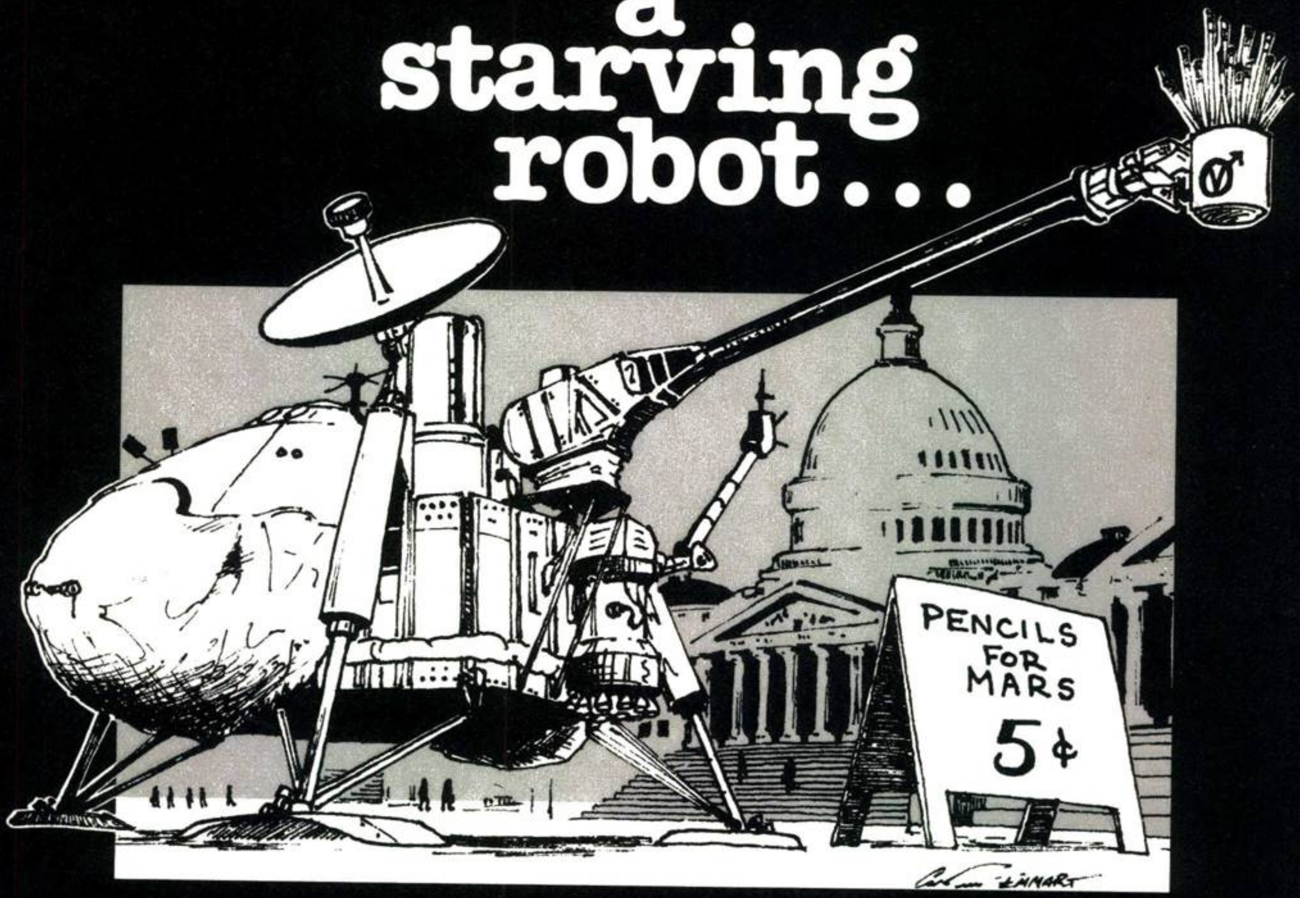
θ
V
ι
-20°
NGC-5897
RS
EI
σ
Hydra
Lupus
Centaurus
-30°
-30°
16h
15h
14h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (2000)	Dec.
Struve 1837	★^{2}	6.7,8.5	1.2″	14h22m	-11°27′	14h25m	-11°40′
V	♏★	9.0-14.5	255d	14h38m	-17°27′	14h40m	-17°40′
Mu (μ)	★^{2}	5.8,6.7	1.7″	14h47m	-13°57′	14h49m	-14°09′
Alpha (α)	★^{2}	2.9,5.3	230″	14h48m	-15°50′	14h51m	-16°00′
18	★^{2}	6.0,10.2	20″	14h56m	-10°57′	14h59m	-11°09′
Delta (δ)	♓★	4.8-5.9	2.3d	14h58m	-08°19′	15h01m	-08°31′
Iota (ι)	★^{3}	4.7,9.7,10	59″, 1.8″	15h09m	-19°36′	15h12m	-19°48′
Beta (β)	★	2.6	—	15h14m	-09°12′	15h17m	-09°23′
NGC-5897	●	8.6	7′	15h14m	-20°50′	15h17m	-21°01′
RS	♏★	7.0-12.5	217d	15h21m	-22°44′	15h24m	-22°55′
EI	♓★	9.4-10.4	2.0d	15h31m	-22°50′	15h34m	-23°00′
Struve 1962	★^{2}	6.5,6.6	12″	15h36m	-08°38′	15h39m	-08°47′
R	♏★	9.7-15	242d	15h51m	-16°05′	15h54m	-16°14′
48	★	4.9	—	15h53m	-14°08′	15h58m	-14°17′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
♏★	*Regular Variable*
∩★	*Irregular Variable*
♓★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§∫	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

Feed a starving robot . . .



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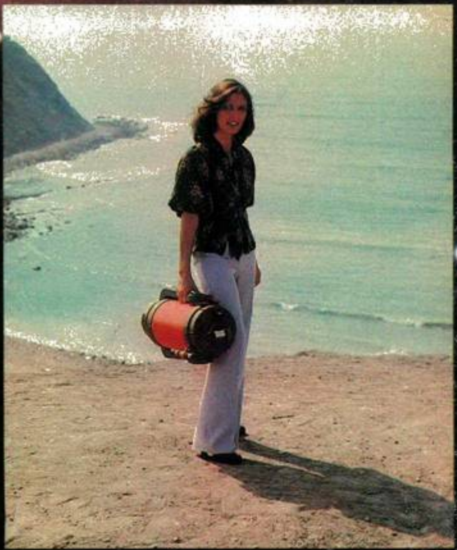

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